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A STUDY OF THE POLLUTION AND NATURAL
PURIFICATION OF THE ILLINOIS RIVER.
II. THE PLANKTON AND RELATED ORGANISMS

W. C. Purdy

Public Health Service
Washington, D. C.

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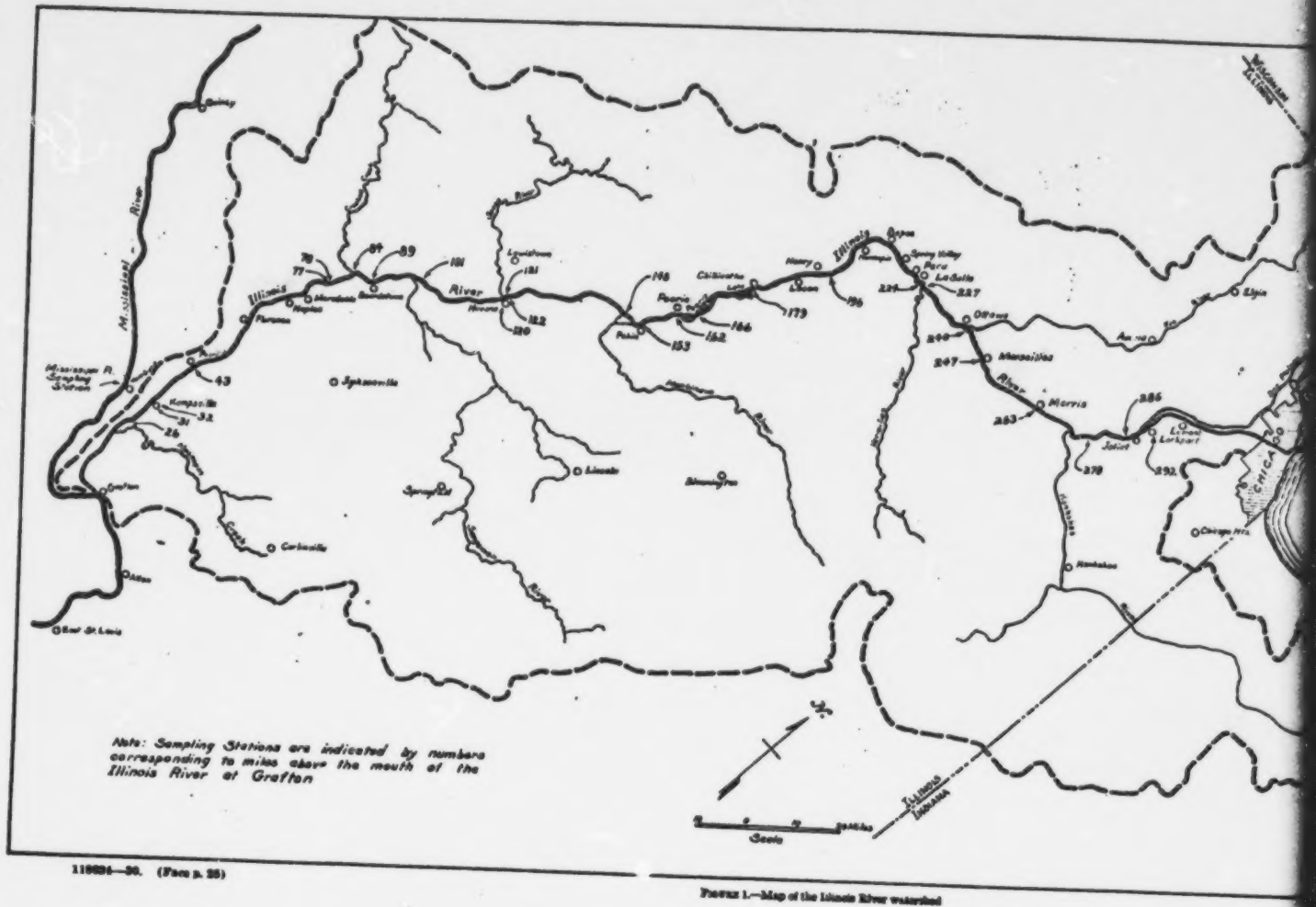
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FIGURE 1.—Map of the Illinois River watershed

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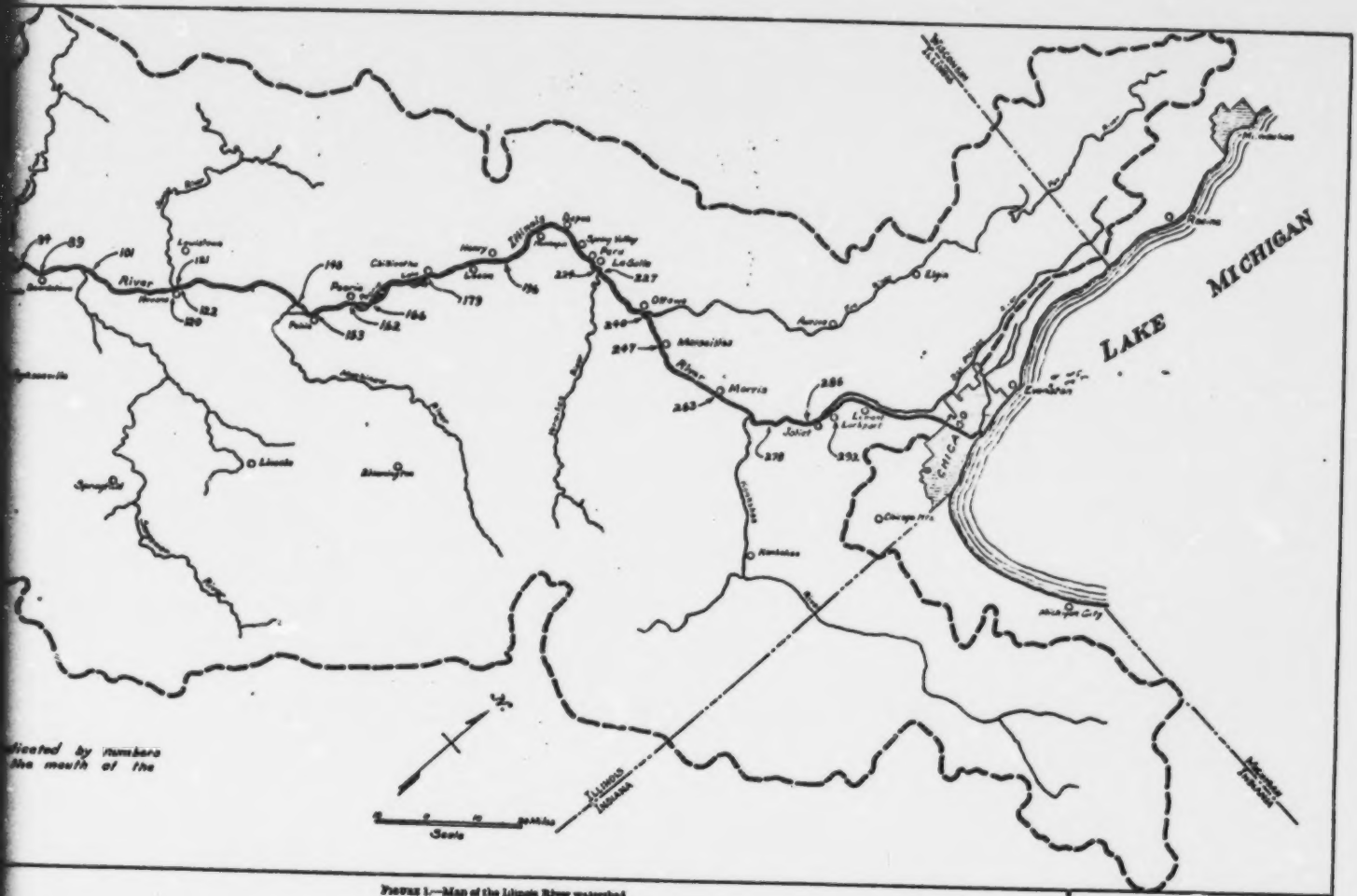


FIGURE 1.—Map of the Illinois River watershed

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A STUDY OF THE POLLUTION
AND NATURAL PURIFICATION
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II. THE PLANKTON AND RELATED
ORGANISMS

By

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U. S. Public Health Service

PREPARED BY DIRECTION OF THE SURGEON GENERAL

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FOREWORD

The presence of a flock of reedbirds in a marshy region causes no surprise, because this is their natural feeding ground when wild rice or other seeds are in season. Similarly, wild ducks, frequently seen, excite no comment, for they feed on such animal life and roots of such plant life as are normal to the marshy areas. If an occasional hawk, mink, or other predatory animal is seen, no special interest is aroused, for these also belong to the normal, everyday life of the marsh because of the food they obtain by preying upon the birds. But the sudden appearance of a dozen or more buzzards (of well-known food habits) circling about over this marsh arouses interest at once. We know that an unusual event has taken place—an animal carcass of sufficient size to attract these buzzards is now present in the marsh, and in a day or two, perhaps in a very few hours, the carcass will disappear because of the food habit of the buzzards. Then the buzzards also will leave, because their only interest in the marsh lies, not in the plants, the blackbirds, or the ducks, but in the possible and occasional presence of a carcass.

Reproducing the essential situation in terms of microscopic water organisms (instead of marsh plants, reedbirds, minks, and buzzards), we may, by use of a microscope, become familiar with the minute plant forms and the minute herbivora, carnivora, and omnivora that constitute the prevailing population of a given water. Minor fluctuations occur in the relative abundance of any of these groups from time to time. But a sudden and persistent increase and predominance of any particular class of organisms attracts our attention, particularly if these have been relatively few or absent in the normal régime, and we suspect at once that abundance of food for such organisms is the explanation of their sudden increase. If these organisms happen to be the kinds that are normally abundant in sewage-polluted water, we are thus led to the conclusion that sewage has entered the stream, and that these organisms will help to remove it.

The plankton proper.—These minute organisms have limited powers of locomotion, or perhaps none at all. They are necessarily confined to that amount of water the volume of which includes their lifetime excursions, except as this water itself moves. Such water, moving and mingling with other water of differing quality, may carry the contained organism into a changed environment which may be favorable or may not be. Just what these vital factors of environment

may be is not fully known, beyond the obvious matters of adequate food supply and absence of destructive agency.

In water known to be polluted with sewage we find, almost invariably, certain plankton organisms in great abundance. In water which we know does not contain sewage, most of these same organisms are absent, and certain others are present which were not found in the sewage-polluted stream. Finally, by sampling the sewage-polluted water at varying distances downstream we find that physical, chemical, and bacteriological evidences of pollution gradually disappear. These same samples show also, that the plankton organisms so abundant when the water was in polluted condition are likewise decreasing in number, and that other organisms like those in an unpolluted stream gradually appear.

These observations have been made many times, and by investigators both in Europe and America. Partly as a result of this work such organisms as are abundant when water is known to be polluted have been termed "pollutional" or "septic" or "polysaprobic" organisms, not because they cause pollution, but because they usually indicate its presence. Similarly, certain other organisms have been termed "clean," or "oligosaprobic," because, as a rule, they are found only in water that is relatively unpolluted. Such classes and groups of organisms as described above have been termed "index organisms," because in a general way, they indicate the prevailing sanitary condition of the water.

Some organisms appear to thrive equally well in polluted or unpolluted water, and obviously can not be classed as index organisms. Various other organisms will apparently tolerate only moderate amounts of pollution. As the actual requirements of various organisms are ascertained by careful, patient study, it becomes increasingly evident that, like fish or clams, certain of these minute plants and animals of the plankton, most of them microscopic in size, exhibit well-marked reactions when industrial waste or sewage is discharged into their aquatic environment, and it seems equally true that certain other forms are apparently affected but little, or perhaps not at all.

The following pages constitute an effort to record not only the presence of certain organisms in the water of a polluted stream but also to set forth, so far as present knowledge will justify, the work that such organisms are doing, and the probable net results of such work in terms of stream purification. The presence of "pollutional" organisms, for instance, means not only that pollutional matter is present, but it also means that the proper workmen are on hand to dispose of such material, with ultimate improvement of the water as a logical result. An ally in the good work is found in the great preponderance, at all seasons, of such organisms as produce an

excess of oxygen. It seems reasonable to regard these minute biological workmen as a factor of hitherto unsuspected importance in stream economy, hence the prominence accorded them in certain tables, and in the text as well.

This study is the biological portion of an investigation of the Illinois River carried out by the United States Public Health Service in 1921-22 under the supervision of Sanitary Engineer J. K. Hoskins. This investigation is a part of the series of studies of polluted streams under the general direction of Surg. W. H. Frost. The biological portion herewith given was preceded by reports of bacteriological and chemical studies which were carried on at the same time as the present study.

Data recorded in such tables as 11, 18, 30, and 46 indicate that the bottom sediments and their contained organisms constitute a pollution index comparable to that furnished by the plankton, or perhaps superior, in that the study of these latter organisms is more readily accomplished. It seems a fact of undoubted significance, when the sanitary status of a stream is in question, that the bottom sediments at a given point yield only such organisms, chiefly worms, as are able to live with a minimum of dissolved oxygen, while at another point the sediments of the same stream will yield a large variety of organisms, chiefly insect larvæ, which breathe by means of gills, as do the fish which are characteristic of our cleaner, well-oxygenated waters.

A number of photomicrographs are introduced in order to acquaint the reader with the predominating organisms (other than bacteria) concerned in biological purification.

Acknowledgment is due to Mr. M. S. Foreman, assistant limnologist, for a very large amount of painstaking work in examining several hundred plankton catches.

CHAPTER I¹

BIOLOGICAL INTEREST OF THE ILLINOIS RIVER

A combination of events has made the Illinois one of the best-known rivers in the country, biologically speaking. Chief among these events are the following:

1. Originally the river was a typical, slow-moving stream draining a large area of fertile prairie and was moderately polluted by sewage from a few small cities. The course of the lower half of the stream was characterized by a very large number of small lakes, bayous, and backwaters, which, with the very broad flood plains, provided ample room for the expansion of flood waters, impounding for a time a large portion in the extensive backwater areas where biological activity was speedily apparent in the heavy production of visible aquatic flora and fauna. Such a biological paradise soon attracted the attention of the veteran biologist, Dr. S. A. Forbes, then director of the Illinois State Laboratory of Natural History, with the result that Professor C. A. Kofoid, superintendent of the Illinois Biological Station, undertook an elaborate study² of the microscopic organisms, or plankton, of the stream and some of the adjacent lakes in 1894 to 1899, inclusive. This was the first comprehensive study of the plankton life of a typical stream to be undertaken in this country. Such a study attracted the attention of many scientific men, and the river thus became known to the biological world.

2. As the above study closed, there came a radical change in the Illinois River by reason of the opening of the Chicago Drainage Canal which delivered the sewage of that city into the Des Plaines River at Joliet, 16 miles above the point where the Illinois River is formed by the junction of the Des Plaines and the Kankakee Rivers. This sewage, flushed through the canal by water pumped from Lake Michigan, greatly increased the volume of the Illinois and increased the speed of its current. The most important change, however, was the great burden of organic matter, chiefly sewage and stockyard wastes, which was turned into the river with the expectation that biological agencies and other natural factors would successfully dispose of such wastes. This method of solving the troublesome problem of sewage disposal for a large city was one that attracted wide

¹ Submitted for publication March, 1920.

² See p. 3 for abstract of this investigation.

2 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

attention on the part of engineers, bacteriologists, sanitarians, and scientists generally.

3. The city of St. Louis, located on the Mississippi River 39 miles below the point where the Illinois River enters, takes its water supply from the Mississippi River. On the day that the Chicago Drainage Canal was formally opened, January 17, 1900, the State of Missouri instituted proceedings in the courts, asking for an injunction against the State of Illinois and the sanitary district of Chicago to the end that the St. Louis water supply should not be polluted. A large number of the leading sanitary experts of the country were called upon for testimony in the case, and meantime both the interested parties started investigations in order to ascertain the facts concerning the numbers of bacteria in the sewage-laden stream at various points along its total course of 357 miles, and to ascertain the real sanitary status of the lower Illinois River as it entered the Mississippi and contributed to the water supply of St. Louis. This legal struggle between two great cities attracted much attention on the part of everybody interested in the legal, the biological, and sanitary aspects of the case, while the public at large was duly informed of the matter by the newspaper accounts. The Illinois River had become known to multitudes.

Subsequent events relating to the publicity schedule of the Illinois River, though deeply significant, are less spectacular than the foregoing. Chief of these significant events are:

4. Progress of extensive reclamation operations, with construction of levees which prevent expansion of flood waters over certain of the low-lying areas, and increase the speed of the river current. The reclaimed backwater areas meantime reduce the areas formerly available for proper digestion of organic waste, growth of organisms which constitute fish food, and feeding and breeding grounds of the fish themselves.

5. Growth of the city of Chicago, with heavy increase in amount of sewage and of stockyard waste overburdening the already polluted Illinois River, which, with reduced area for overflow, limiting levees, and increased volume, must therefore flow more rapidly in its narrowed channel, with the result that each succeeding year its organic matter is carried farther downstream, before the offensive organic content is sufficiently removed. As a visible result of the downstream encroachment of this decomposing organic matter (estimated at 16 miles³ per year), the valuable fishery interests of the lower river have been seriously harmed and threatened with extinction.

¹ Richardson, R. E. (1921), Abstract No. 9.

CHAPTER II
**PREVIOUS BIOLOGICAL STUDIES OF THE ILLINOIS RIVER
AND OTHER STREAMS**

Persistent study of polluted streams has revealed the outstanding natural laws which invariably apply to such streams. These laws are various expressions, under various environments, of two fundamental principles that apply to all living things, aquatic or otherwise, namely:

I. Living organisms respond, within certain limits, to their environment.

II. Activity of organisms may visibly affect their environment.

A number of biological investigations of polluted rivers in this country have served to give expression to the practical workings of these laws. Broadly speaking, streams are apparently much alike, and certain general laws will no doubt apply to all of them. Nevertheless no two streams are alike in all details, and the endless variations and combinations of factors will in time be reflected in the biology of the stream concerned. Any considerable peculiarity of flow, of waste content or of channel conformation, or any other outstanding characteristic, whether physical or chemical, will produce striking differences in the biological history.¹

The following brief abstracts of river studies will serve to tabulate the most important findings of each investigator, and to express the biological behavior that may reasonably be expected under the various environments cited. For convenience each abstract is preceded by a descriptive title which is intended to express the main trend of the results of the study. The exact title of the paper is in all cases stated elsewhere.

- (1) The plankton population of a stream—Interrelations of the various organisms—Chief hydrometric, chemical, biological, and physical factors of environment—Effects of sewage

Prof. C. A. Kofoed conducted a 5-year study² of the Illinois River for the threefold purpose of (1) determining the biological population; (2) studying the life histories and mutual dependencies of these

¹ Case in point.—(1) The broad shallow flats bordering the Potomac River favor a very heavy growth of submerged plants which, in turn, produce sufficient oxygen to reduce much of the sewage of Washington. (2) Mine drainage and steel-mill waste in the sewage-polluted Monongahela apparently make the bacterial count very low and also kill all minute plankton life, leaving only the larger forms.

² The Plankton of the Illinois River, 1884-1889, with introductory notes upon the Hydrography of the Illinois River and its Basin. By C. A. Kofoed, Bull. Illinois State Lab. of Natural History, Vol. VI, Art. II, November, 1903. Also Vol. VIII, Art. I, 1908.

organisms, and (3) studying and analyzing the factors of environment. This investigation was carried on from 1894 to 1899, and was thus completed before the opening of the Chicago Drainage Canal, in 1900, introduced a deluge of sewage into this river.

This was the first comprehensive study of the plankton life of a stream to be undertaken in this country. The data gained, together with the discussion and interpretation, which forms a large part of the study, constitute a valuable contribution to our knowledge of plankton activities. Incidentally, and very fortunately, this study of the normal river, before its excessive pollution by sewage from the drainage canal, establishes a broad foundation on which to build the later comparative studies by Professor Forbes and Mr. Richardson, and finally the present study, so that the whole series presents a picture which shows in perspective the unpolluted stream, with valuable fisheries; the increase in volume and the change in character of the upper river, on the advent of the flood of Chicago sewage, together with the train of biological events resulting from this influx of sewage; and later the results of increasing the burden of sewage in the already sick stream, expressed by the gradual advance, downstream, of the effects of pollution, also by the disappearance of food supplies for fish, and to a great extent of the fish themselves, this latter exodus being hastened by extensive reclamation, for agricultural purposes, of many of the shallow bottom-land lakes, which formerly provided adequate feeding and breeding grounds for the fish.

Kofoed's samples, 645 in number, were collected from seven points in the region of Havana, which is about midway between the river's source and its mouth. One collecting station representing 235 of the above samples was in the river channel, one in the Spoon River (a local tributary) and the remaining five were in adjoining backwaters and lakes which at that time characterized the river bottoms. The catches were so distributed over the entire 12 months of the several years as to form a fair basis for the determination of the seasonal fluctuations.

Very briefly summarized, the more important findings of Kofoed's study are as follows:

1. Certain ciliates are very abundant during the height of sewage contamination and bacterial development. They are very important in the economy of the plankton, as they feed chiefly on bacteria, decaying organic matter, and the smaller algae, and are themselves eaten by rotifers. These ciliates are active agents in the reduction of sewage, in destruction of the bacteria of decay, and in purification of sewage-laden waters, transferring the matter therein to higher forms of animal life.

2. Plankton production is essentially rhythmic or periodic, the waves or "pulses" being from three to five weeks duration. Ampli-

tude of pulses is affected by local influences and by season. Rising temperature, hydrographic stability, decaying vegetation, or access to sewage tend to increase plankton, while declining temperatures, dilution of fertilising material, access of flood waters, and increase of current all tend to decrease plankton. Initial causes for plankton pulses are traceable through complex food relations which extend from the larger animal forms back to the minute algae and other synthetic organisms. These in turn are dependent on sunlight and on dissolved matter in the water. Another line is traceable from certain ciliates and flagellates back through the bacteria, which owe their chief food to the contamination, usually sewage, which causes the high bacterial growth.

3. The presence of considerable amounts of organic matter, such as sewage, apparently initiates a well-defined series of biological events, beginning with high bacterial content and large numbers of ciliates. Minute chlorophyll-bearing organisms, both algae and certain of the Mastigophora, then appear, to be followed usually by larger organisms (rotifers, rhizopods, and crustacea), which find most of their food in the more minute animals and plants.

4. The age of the water is a vital factor in the production of plankton, a long time-factor permitting adequate decomposition of the contained organic matter, which, in turn, provides sufficient food, directly or indirectly, for the aquatic population. Conversely, a short time-factor is unfavorable to plankton growth.

5. There is little correlation between seasonal flux in chemical conditions (as shown by analyses) and seasonal course of plankton production. Nitrogenous matters are influenced, especially by rapid growth of diatoms, but changes are not uniform nor proportional.

6. Temperature affects plankton profoundly. It was noted that when temperature was below 45° F. (-7° C.) the plankton content of the river channel was only 9 per cent of that present when temperatures were higher.

7. Submerged non-rooted vegetation, such as algae, absorb their food materials direct from the water, competing with the minute plants of the plankton for this nourishment. Rooted water plants, on the other hand, derive most of their food from the bottom mud, and the decay of their stalks enriches the water, thus adding to the dissolved food material available for minute plants of the plankton. Accordingly the plankton yield of an alga-filled pond is usually much less than the yield from a pond containing rooted and emergent vegetation as its chief plant life.

8. Light affects plankton production. The half year with more illumination and fewer cloudy days produced from 1.6 to 7 times as much plankton as that with less illumination and more cloudy days.

Seasons of unusual cloudiness are accompanied by depression in production.

9. The plankton of the river channel is subject to great seasonal and annual variations. As a rule there is minimum production in January and February, rising production in March, maximum production in late April (about) and declining production in June, the yield fluctuating with gradual decline until December.

10. Individual years may vary greatly from the general rule just stated, owing chiefly to varying climatic conditions. An early spring accelerates and a late spring retards the vernal maximum. Heavy plankton production may occur when temperature is low, and a considerable yield is possible even under the ice sheet unless conditions of stagnation occur.

11. Diatoms are frequently very abundant and are of great importance and significance in the food supply of higher organisms. Abundance of other minute organisms containing chlorophyll provides food for large numbers of rotifers.

12. Aquatic insects are important by reason of many food relations connecting them with the smaller plankton organisms.

(2) *Speedy biological digestion of sewage-filter effluent by a small slow stream*

A valuable study² covering two years was carried out by Mr. Weston and Mr. Turner on the history of a small otherwise unpolluted stream (the Coweeseet) when a relatively large volume of sewage-filter effluent was turned into it. The essential factors and conditions in this study were as follows:

(1) An unpolluted stream, the flow of which varied from half a million to 25,000,000 gallons daily, was augmented by about 2,000,000 gallons daily of partly purified effluent from sewage filters. About three-fourths mile below the point of pollution this stream is joined by another two or three times as large and unpolluted.

(2) The dry-weather flow of the small stream was so low that below the sewage outlet the stream frequently contained more of the sewage effluent than of the normal water.

(3) The raw sewage was treated on 37 acres of sand beds, 60,000 gallons per acre daily. Raw sewage was highly septic and contained spent dyes, leather dust, and other shoe-factory wastes.

(4) Weekly chemical, bacteriological and biological samples were taken during the first year at nine selected points covering about 3 miles of the stream. Samples were taken less often during the second year.

² Studies on the Digestion of a Sewage-Filter Effluent by a Small and Otherwise Unpolluted Stream, By Robert Spurr Weston and C. E. Turner. Contributions from Sewage Experiment Station, Mass. Inst. of Tech., Vol. X, 1917.

The outstanding objects of the study were to discover to what extent a stream would receive and digest, without causing nuisance, the effluent from a sewage purification plant; to determine the most important factors concerned in such digestion; and to ascertain approximately the speed with which such action was carried out.

FINDINGS

- (1) The stream, on receiving the sewage effluent, lays down a "pollution carpet," or false bottom, consisting largely of precipitated organic and mineral matter. This carpet contains organisms that are more nearly representative of the sanitary status of the stream than are the organisms found in the supernatant liquid.
- (2) The entrance of organic matter into the stream increases plant and animal life in a series, beginning with the lowest and ending with the highest forms, each class appearing along with a definite food material. The organisms which most clearly indicate the degree of pollution are bacteria, protozoa, and diatoms.
- (3) In this stream, as in others, the smaller, shallower, and more nearly stagnant the body of water and the more highly clarified the effluent, the more rapid is the succession of animal life and the more rapid and complete the purification. In this stream, when discharging less than 5,000,000 gallons and receiving 2,000,000 gallons of sewage effluent daily, the chief radical changes occur within the first mile, with only very gradual changes thereafter.
- (4) The dissolved oxygen tends to decrease until the excessive growth of animal life, favored by pollution, ceases. This factor outweighs both the normal reoxygenation, and the oxygenating effect of plant growth.
- (5) The rate of oxidation of nitrogenous compounds varies with the season and with the intensity of organic growth; it is very rapid in summer and hardly noticeable in winter. Chemical changes in the stream are due to bacteria chiefly. The higher animal organisms are important by removing an excess of lower organisms.
- (6) Certain rotifers and small crustacea may indicate the presence of simple green algae and not necessarily of sewage pollution. Certain worms and insect larvae assist in digesting the debris accumulated in the "pollution carpet."
- (7) The return of the stream to normal biological conditions is more rapid than its return to a normal chemical condition. The rate of chemical change is much less rapid below the point where biological processes have become somewhat inactive.
- (8) Water mold (*Leptomitrus*) appearing in December, spreads a thick mat over the banks and bottom of the stream until, in spring, it decomposes, thereby greatly increasing the suspended matter in the water, and is succeeded by growths of algae and higher plants.

(9) Information gained relative to the stated objects of the study may be recorded as follows: Slowly moving shallow water is able within the first mile of its course to digest and highly purify these sewage effluents in relatively large volume. The process of digestion is almost wholly biological and is very sensitive to temperature and to amount and character of plant and animal life. The whole study reveals the extreme importance and the energetic action of certain plants and animals in purifying a stream receiving sewage effluents.

(10) Effective sewage reduction traceable to re-aeration, re-oxygenation, and thorough mixing as tides force polluted water through plant-filled shallow areas bordering the river channel.

A biological study⁴ covering about one year was made on the Potomac River in 1913-14, as a part of an investigation concerning the self-purification of the river and the consequent sanitary condition of shellfish in the oyster beds of the lower Potomac. Plankton samples, bottom sediments, and plant life in season were collected weekly from representative portions of the river. A detailed study was made concerning the significance of the extensive open flats or shallow-water margins that border the narrow, deep channel of the river proper. These great areas, filled (in summer) with a heavy growth of submerged aquatic plants, serve as expansion areas into which the sewage-polluted water is forced twice daily by the flood tide and is drained into the channel again by the ebb tide.

The more important findings were as follows:

(1) The tides compel thorough mixing of the sewage with a very large volume of water. Also by checking and reversing the normal current twice daily the tides greatly increase the time required for the sewage introduced at Washington to reach a given point downstream, thus increasing by many times the effective length of the river.

(2) The extensive shallow flats, filled with submerged aquatic plants, function as a mixing device for water and sewage forced through by the tides, as delay stations for adequate biological action and breeding of organisms, and finally as oxygenators of the polluted water by reason of the enormous amount of oxygen given off by photosynthetic action of these plants. Essentially these flats are natural sewage-disposal plants.

(3) The ebb-tide water draining from the flats back to the channel is distinctly better in quality and higher in oxygen content than the flood-tide water forced upon the flats at some hours previously. The amount of this improved water thus returned to the channel from the several flats a few miles below Washington is approximately equivalent

⁴ Potomac Plankton and Environmental Factors. By W. C. Purdy (1916). Pp. 120-151 in Hygienic Laboratory Bulletin No. 154.

lent to the continuous flow of a tributary about the size of the Ohio River at Wheeling, W. Va., at low-water stage.

(4) Greatest production of oxygen by the submerged plants takes place on sunny days. The actual amount of oxygen produced by one flat daily during the summer was sufficient for the complete oxidation of nearly 8,000,000 gallons of sewage daily. This flat constituted about one-tenth of the similar areas a few miles below Washington.

(5) So far as organisms of the plankton and of the bottom sediments were concerned, there was no evidence of sewage pollution in the oyster-producing areas of the lower Potomac.

(4) Excessive pollution indicated by destruction of native snails and bivalves—After diversion of sewage, a polluted stream may recover in two years

A detailed study⁴ of the molluscan fauna of the Big Vermilion River (Ill.) was made in 1922 by Mr. F. C. Baker. This study had special reference to the modification of molluscan life as the result of pollution by sewage and manufacturing wastes.

The above river is a small stream about 90 miles long, draining 1,500 square miles and with an average fall of $3\frac{1}{2}$ feet per mile.

Crayfish and mussels became abundant at about the same portion of the stream; i. e., about 16 miles below the place where the stream was heavily polluted by sewage.

It was found that the pollution of the twin cities (Urbana and Champaign) exercised a marked injurious effect on the normal fauna of the stream, especially fishes and mussels.

Reference is made to the injurious effects of pollution of various kinds as shown by the study of various streams throughout the country, and the relationship of this condition to human welfare:

(1) Studies by Ortmann (1909) show that whole stretches of the Allegheny, Ohio, and Monongahela Rivers have been made into deserts, as far as the animal life is concerned, by the large amount of poisonous substances discharged into these streams by the mines, oil industries, and chemical and other factories that border these rivers.

(2) Essentially the same condition prevails in many places along the Susquehanna River.

(3) The Illinois River is cited as a classic example. Due to a deluge of sewage by the opening of the Chicago Drainage Canal in 1900, animal life has been almost excluded from the upper river, and this condition of extreme pollution is encroaching farther south each year, due to increase of sewage incident to the growth of the city of

⁴ The Molluscan Fauna of the Big Vermilion River, Ill. By Frank Coates Baker, Illinois Biological Monographs, Vol. VII, No. 2, April, 1922.

Chicago. At present (1922) the lower limit of strong pollution is about 160 miles south of Chicago, near Peoria. Forbes and Richardson made numerous studies on the biological phases of this river.

(4) Wilson and Clark, studying the Kankakee River, 1912, found that all mussels had been killed in the extreme lower portion of the river, where the polluted Des Plaines, carrying the Chicago sewage, unites with the Kankakee, and the effects of this pollution work upstream a little way. The same investigators found (1912) that in the Maumee River, refuse from gas works had killed the mussels.

(5) The Genesee River, in New York, under observation by F. C. Baker for 27 years, affords a striking example of the injurious effects of sewage pollution on animal life, and of the recovery of the stream as to this animal life when the pollution has been removed from the stream. Water-breathing mollusks, very abundant in 1892, became less and less numerous, as sewage pollution became more abundant. In 1907 the water breathers had disappeared, but a few air breathers (*Galba*, *Planorbis*, and *Physa*) still held out, until in 1910 these also had disappeared. Further examinations in 1913 failed to reveal any living mollusks.

During 1912 Professor Whipple studied the effects of pollution in this same river. The dissolved oxygen, in July and August, varied from 5 to 41 per cent of saturation. Bacteria were very abundant (1,650,000 per c. c.) near the source of pollution, dropping to 67,000 near the mouth of the river. In 1917 a large part of the sewage was diverted from the river and treated. As a result, examinations in 1919 showed the return of many of the mollusks, and of various other forms of aquatic life. It is significant that this return to normal fauna was accomplished in only two years after diversion of the main part of the sewage from the river.

In the study of the Big Vermilion River, Mr. Baker found the usual injurious effects of pollution. The combined sewage of the twin cities, with population aggregating 30,000, amounted to about 1,500,000 gallons daily. This sewage, untreated, was flowing into the Salt Fork (a tributary of the Big Vermilion) but the total stream flow below this point was only 3,000,000 gallons daily. This means that the sewage added to the stream formed one-half of the total water flowing down the Salt Fork. All mussels were killed or driven out for a distance of 14 miles downstream from the point of pollution, and a normal abundance of mussels and other clean-water fauna was not found short of 20 miles downstream. The only animal life in this polluted section of the stream consisted of sludge worms and certain protozoa which were able to survive such conditions.

(5) Plankton and bottom sediments a valuable source of evidence as to the sanitary status of a sewage-polluted stream

A biological study* of the Ohio River made during 1914 and 1915 may be briefly summarized as follows:

1. The Ohio River, a natural "Mason and Dixon's line," receives from the north tributaries that are affected by rigorous winter conditions, the spring thaw unloading accumulated organic matter in large quantities. Tributaries from the south, with mild winters prevalent, more continuously bring organic matter which has meantime been in favorable temperature and environment for partial purification.
2. The river, geologically young, with erosion of banks and channel, is highly turbid much of the time, and sunlight is at such times limited in its favorable action on the growth of minute chlorophyll-bearing organisms which, in turn, constitute much of the food supply of the larger animal organisms.
3. As the river flows seaward, receiving tributary waters, industrial wastes, and sewage the mixing of these varying constituents is effected by the numerous riffles, bars, pools, and islands that characterize the Ohio Channel and that cause much variation of speed, of depth, and of relative surface exposure. Further mixing, and aeration as well, is effected by passage of the water over numerous dams.
4. Impounding of water during low stages by 38 dams favors biological activity by the increased time thus available for decomposition of organic matter.
5. Flood conditions bring organisms from distant points, interrupt favorable conditions of quiet for local plankton, and cause turbidity which deprives plantlike organisms of sunlight thus checking their growth. Flood time plankton is difficult of interpretation and is of questionable value particularly as to local conditions.
6. Organic matter of many kinds, introduced chiefly at Pittsburgh, Cincinnati, and Louisville, apparently constitutes the chief reason for the abundance of plankton and of mud organisms near these cities.
7. The small aquatic life at any given point in the river varies with respect to season and temperature, rainfall, and amount of sunlight. Greatest abundance of organisms occurs during the warmer weather. However, if conditions are stable and water is clear, a heavy growth of plantlike organisms, chiefly diatoms, may occur during cold weather. Such a diatom growth was noted in the Ohio River in November, 1914, also in November, 1915, and in September, 1916.
8. The water in the Monongahela River is abnormal in that the reaction is acid, due apparently to the large amount of mine drainage

* A study of the Pollution and Natural Purification of the Ohio River.—I. The Plankton and Related Organisms. By W. C. Purdy (1922). Public Health Bulletin No. 131.

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and steel-mill waste. The plankton content of this tributary is likewise abnormal in that the organisms commonly found in such a highly polluted stream are not present. Certain other forms are present in very limited variety but in large numbers.

9. Bottom sediments represent an accumulation of matter previously suspended in the water. Such deposits constitute an index as to the condition of the overlying water unless floods or currents remove these sediments too frequently to permit the development of such physical conditions and biological content as will faithfully reflect the local environment. These bottom deposits fluctuate more slowly and less widely than does the overlying water, and their testimony as to the prevailing sanitary status of the water is valuable accordingly. In practically every instance in the Ohio investigation the plankton and the bottom sediments are in agreement in their testimony as to the condition of the water.

10. The Ohio River is nearly 1,000 miles long, from Pittsburgh to its mouth near Cairo. Study of the plankton and of the bottom deposits indicates the following:

(1) Initial heavy pollution at Pittsburgh is distinctly reduced by the time the water reaches Wheeling (98 miles).

(2) The small amount of sewage added at Wheeling has but little effect on the large volume of water.

(3) On reaching Cincinnati, 480 miles below Pittsburgh, the river (now more than four times as large as at Pittsburgh), shows only slight evidence of the initial heavy pollution.

(4) The addition at Cincinnati of the wastes from over half a million population produces a noticeable secondary contamination, but proportionately only about one-eighth as great as that at Pittsburgh.

(5) At Louisville, 600 miles below Pittsburgh, the pollution added at Cincinnati has nearly disappeared.

(6) The untreated sewage from the 300,000 population of Louisville produces only a mild tertiary contamination of the large volume of fairly good water.

(7) In the final stretch of river below Paducah (930 miles below Pittsburgh) the stream is about nine times as great in volume as at Pittsburgh on account of large tributaries which meantime add very little polluting material. Effects of sewage from Evansville and Paducah, aggregating about 100,000 population, are hardly noticeable a few miles below Paducah. During low-water stages neither plankton organisms nor bottom sediments show evidence of any considerable pollution in the lower Ohio as it is about to flow into the Mississippi.

- (6) The plankton, the bottom and shore conditions, and the chemical characteristics of the upper Illinois River when overburdened with sewage—Conditions after 10 years

It is most fortunate that only a few years after the opening of the Chicago Drainage Canal a careful study,⁷ chiefly of the upper Illinois River, was carried out by Professor Forbes and Mr. Richardson. This investigation comprised the following main items: (1) Study of plankton collected three or four times per month throughout an entire year (1909-10) from the Illinois River at Havana and from two adjacent bottom-land lakes. Also plankton from the upper river from its origin at Dresden Heights to Chillicothe in June, July, and August, 1911. (2) Chemical studies of the upper river from its origin to Chillicothe during 1910 and 1911. (3) Study of larger life, particularly fish and certain bottom and shore organisms, was emphasized during 1911. Certain additional collections, both biological and chemical, were made for comparative study. These included a series of oxygen determinations for the entire length of the river in 1912. In connection with the above specific items a large amount of valuable field work was done.

The general object of this investigation was to discover the more important results traceable to the flood of Chicago sewage and, from the accurate scientific data obtained from such study to provide a just appraisal of the existing situation from a biological point of view in order that all the interests involved might be seen more nearly in their real values and in proper perspective, to the end that any further utilization of the river or of its adjacent lowlands might proceed with due regard to the general public good.

In view of the nature of our present study, we append herewith a somewhat detailed review of the study by Doctor Forbes and Mr. Richardson, presenting as it does an excellent background for the consideration of later biological data from the same sewage-burdened stream.

The average amount of plankton after the opening of the canal was 5.07 cubic centimeters per cubic meter of water, as compared with 3 cubic centimeters per cubic meter previous to the opening. This average increase of 69 per cent was traceable to favorable plankton environment resulting when the largely increased volume of water overspread fertile bottom lands, and sewage from Chicago provided further large amounts of organic matter as food for microscopic organisms.

In correlating distinguishable stages of pollution with their respective chemical and biological characteristics, the river was divided into four sections, in the order of diminishing impurity, and designated by the terms "septic," "polluted," "contaminated," and, finally, "clean water." Analogous terms were applied to the characteristic organisms found in the respective waters. The following is a summary of the chief findings in these four zones of pollution.

⁷ Studies : the Biology of the Upper Illinois River. By Stephen A. Forbes and R. E. Richardson, A. M. Bulletin Illinois State Laboratory of Natural History, Vol. IX, Art. X, June, 1913.

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SECTION 1

Sanitary canal at Lockport and Des Plaines River at Lockport. (This is about 33 miles below the source of the sanitary canal, which, after a flow of 38 miles, empties into the Des Plaines River at Joliet, Ill.)

Character.—Septic.

General and chemical conditions.—In canal, water clear. Offal, human excrement, and general refuse stranded or floating, but little decayed. Noticeable sewage odor. Sludge with foul odor. Dissolved oxygen averaged about 31.9 per cent of saturation. In Des Plaines River, water grayish. Decomposition well advanced. Foul privy odor. Conditions less offensive during cooler weather.

Biological content.—In canal, an occasional living fish. Many dead ones, floating or stranded along shore. (Fish were a common Lake Michigan species.) No animal life in bottom sludges. Scattered algae along edges of canal harbored the septic rotifer *E. actinurus* and the protozoa *Bodo*, *Vorticella*, *Oikomonas*, and *Anthophyes*, also septic. In Des Plaines River, bottomstones covered with sewage fungus (*Sphaerotilus*) and blue-green algae. *Anthophyes*, *Carchesium*, *Paramecium*, and other septic protozoa abundant. Various less septic forms present. No fish in September, a few in November, but in dying condition. Many oligochaete and nematode worms in sludge. No mollusks or crustacea.

SECTION 2

Des Plaines River at Dreden Heights (16 miles below mouth of the sanitary canal) and Illinois River from this point to Marseilles, a distance of 26 miles.

Character.—Polluted.

General and chemical conditions.—In Des Plaines River, water grayish, with privy odor. Dissolved oxygen averaged 13.1 per cent of saturation. In Illinois River, water grayish and clouded with tufts of sewage fungus (*Sphaerotilus*). Masses of putrescent material floating on warmest days. Gas bubbles from bottom. Foul odor from both water and sludge. Dissolved oxygen ranged from 3.1 to 16.4 per cent of saturation. Unpolluted Kankakee (tributary) showed dissolved oxygen content of 108 to 127 per cent of saturation.

Biological content.—In Des Plaines River, large amounts of *Sphaerotilus* and *Carchesium*. The blue-green algae *Oscillatoria* and *Phormidium* were frequent. Other algae present during cooler weather. No fish; no vertebrates except one frog. Many dead mollusks. Air-breathing beetles common. No sponges, hydroids, leeches, planarians, or crustaceans. In Illinois River, *Sphaerotilus*, *Carchesium*, and *Vorticella* abundant. *Colpidium* and *Rotifer actinurus* present. Fish absent except an occasional specimen. Fungi and *Oscillatoria* in sludge; also immense numbers of worms (*Tubifex*). No mollusks, crayfish, or larvae of May fly or dragon fly. Conditions a little better in cooler weather.

SECTION 3

Illinois River from Marseilles (42 miles below mouth of sanitary canal) to Starved Rock, a stretch of 16 miles.

Character.—Contaminated.

General and chemical conditions.—Water grayish. Disagreeable odor. No gas bubbles. Dissolved oxygen about 16 per cent of saturation. Advent of Fox River (relatively pure) and passage of main stream over dam help to improve conditions at Starved Rock, where dissolved oxygen averages 43.6 per cent of saturation near north shore (due to Fox River) and 35.9 per cent near south shore.

Biological content.—*Sphaerotilus*, *Ceratomyxa*, *Epistylis*, and other septic organisms very few. At Starved Rock the only sewage organism found is small amounts of *Sphaerotilus*. Fish in small numbers along edge of river, farther downstream are found in some variety in midchannel, and at Starved Rock are moderately abundant. Blue-green algae (pollutional) fairly common near Marseilles, but scarce at Starved Rock, green algae increasing meantime. Some worms (*Tubifex*) in bottom mud. Insect larvae, snails, crawfish, leeches, etc., more numerous.

SECTION 4

Illinois River from Starved Rock (56 miles below mouth of sanitary canal) to Chillicothe, 107 miles below the canal. This section is 49 miles long.

Character.—Relatively pure water.

General and chemical conditions.—Water very slightly grayish, nearly normal; becomes greenish toward Chillicothe, and the slight odor of sewage disappears. Only in winter do bottom sludges show offensive odor. Dissolved oxygen 23 to 28 per cent of saturation in midsummer, reaching maximum of 82 per cent in November.

Biological content.—Septic and pollutional organisms only occasional or absent. Fish numerous enough to justify commercial fishing. Green algae predominate, the blue-greens being only occasional. Water is made green by large amount of minute chlorophyll-bearing plankton. Large variety of insect larvae and of mussels, snails, and crustacea. Sponges, leeches, bryosoa, and planarians are fairly common. *Tubifex* is rare in bottom sediments.

This investigation by Forbes and Richardson thus indicates that a water burdened with sewage and "sick" according to all available evidence has meantime a characteristic biological content which is totally different from that shown in the lowest section studied, at which time the physical and chemical conditions also indicate that self-purification is far advanced. The recovering water is now 107 miles below the mouth of the drainage canal, and it still has 180 miles to flow before it reaches the Mississippi River.

(7) Heavy production of small bottom and shore fauna in an inland stream, and the importance of such organisms as food for fish.

An investigation^{*} was carried out by Mr. R. E. Richardson extending over three summers and covering a 180-mile section of the Illinois River between Chillicothe and Grafton, together with the more important bottom-land lake areas adjacent to the river in the section studied. This work was done July, 1913, to October, 1915. The main purpose was to secure data concerning: (1) the productiveness of the river and of the adjacent lakes in those small animal forms which constitute the principal food of fish; (2) the content of organic matter, chiefly nitrogen, which in the last analysis was responsible for the yield of small fauna in the various waters studied, and (3) the correlating of the foregoing data with the fish yield in the extensive

^{*} The Small Bottom and Shore Fauna of the Middle and Lower Illinois River and Its Connecting Lakes, Chillicothe to Grafton: Its Valuation; Its Sources of Food Supply; and Its Relation to the Fishery. Ill. Nat. Hist. Survey, Vol. XIII, Art. XV, 1921.

fishery operations along the river. Or, quoting the author, the study is—"Essentially a soil survey of these aquatic properties, for the beds and weedy margins of rivers and lakes are a natural soil of various fertility, of which the animals, mainly univalve mollusks and a few kinds of insect larvae, are the crop, harvested chiefly by fishes, these being harvested in turn by man."

Representative organisms were obtained from the bottom mud by dredges, and from the marginal aquatic weeds by inverting these in a submerged bucket and shaking to dislodge the fauna population. Forty-one cross sections of the river were thus studied in the 180-mile stretch, yielding 387 collections. Additional collections to the number of 385 were taken in the adjoining bottom-land lakes.

Knowing the area covered by each haul of the dredge, and ascertaining, by suitable soundings, the approximate bottom acreage covered by mud, it now became possible to summarize the results of the hauls and to state the yield of small organisms in the river and in the adjacent lakes in terms of pounds per acre.

The essential hydrographic and physical features of the river at the time of this study were as follows:

At Chillicothe the river expands to a width of nearly a mile. This wide portion, about 18 miles long, is known as Peoria Lake. The water is shallow, except in the channel, and movement, even in channel, very slow, about 0.6 mile at flood stage and half that rate at low-water stage. From Peoria, at foot of lake, to Pekin (about 10 miles) the flood-stage current averages 2.17 miles per hour. From Pekin to Florence (97 miles) the flood-stage current varies from 0.75 mile per hour to 1.72 miles per hour. The lower stretch of river from Florence to the mouth at Grafton (about 55 miles) has a flood-stage current averaging slightly over 2 miles per hour. The low-water velocities are one-half the flood-stage rates.

The bottom-land lakes adjacent to 59 miles river length (Copperas Creek to La Grange) were included in the examinations. This comprised that part of the river valley which was most richly supplied with lakes and back-water areas.

FINDINGS

1. The river system varies enormously in the productiveness of its different parts. Greatest production is found in the weedy margins of the shallower lakes, while poorest production takes place in those parts of the river channel where current is sufficiently swift to prevent accumulation of sediment. Consistently, in the river itself, greatest production is found where current is sluggish and bottom sediments have accumulated.

2. In the most productive section of the Illinois River system (just above Havana) the small fauna of the lakes averages in weight about twice as much as that of the river.

3. At ordinary high-water levels the river current from Chillicothe to the mouth varies from 1 to 2 miles per hour, according to slope of bottom, width of bed, and presence or absence of obstructions. At ordinary midsummer levels the variation in current is from half a mile to 1 mile per hour.

4. Above Havana the river bed contains a deep layer of black mud. Below Havana this disappears gradually and firm bottom of clay or of sand takes its place. Most of the bottom-land lakes have bottoms of deep black mud.

5. From Chillicothe to La Grange (103 miles) the animal life is almost wholly mollusks (86 per cent to 99 per cent), but below La Grange insect larvæ (chiefly of caddis and May fly) become fairly abundant, while mollusks decrease in relative numbers. Mollusks make up the principal small animal life of the bottom-land lakes also.

6. The richest sections of the river floor are those with the least average slope and slowest current, and therefore most abundant sediment. Quantity of bottom fauna diminishes rapidly downstream from Chillicothe, averaging 555 * pounds to the acre for the upper 60 miles, 88 pounds per acre for the next 42 miles, and 10 pounds per acre for the lower 77 miles. General average for the river channel from Chillicothe to the mouth (180 miles) was 261 pounds per acre. The highest yield was from the section of river between Copperas Creek and Havana (17 miles). This averaged 2,693 pounds per acre, and the lower portion of this same section showed a local yield of 5,196 pounds per acre. These heavy yields are ascribed largely to the sluggish current and heavy sediments that prevail in this section.

7. Bottom-land lakes yielded an average of 255 pounds per acre, nearly the same as the average yield of the entire river—261 pounds—from Chillicothe to the mouth. But the small weedy lakes of the same locality, near Havana, yielded a *weed fauna* averaging 2,118 pounds per acre. In general, the total yield of these lakes averaged about twice as great as the yield of the richest sections of the river opposite these lakes.

8. Analysis of the bottom muds and estimate of the nitrogen content of the total bottom fauna per acre seemed to indicate that the sediment contained nitrogen several hundredfold greater than that represented by the flesh of the small-animal population therein. Similar chemical analyses show that the bottom sediments of the lakes are richer in organic matter than are the sediments of the adjacent river.

* Weight of shells of mollusks deducted.

18 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

9. The plankton of the river passing Havana in a year amounts to about 200,000 tons live weight, or 4,000 to 10,000 tons dry weight.

10. An estimated total of 600,000 tons dry weight of organic matter, suspended and dissolved, passed Chillicothe in 1914. This is 60 to 150 times the dry weight of the plankton that passed Havana in a year.

11. The river plankton is constantly settling to the bottom to an important degree. This is shown by the composition of the bottom ooze and by the stomach contents of small invertebrates living on and in this ooze.

12. There is evident loss of plankton downstream from Havana. After due allowance for dilution by tributaries, this loss still amounts to about 62 per cent between Havana and Grafton at the river's mouth. Observations were made during nine months of the growing season. Losses were greatest when current was slowest and settling consequently greatest. Meantime, nitrates increased from Havana downstream, so plankton losses were not due to lack of food for such forms as utilized nitrates.

13. Apparently, the lakes, rather than the river, constitute the better feeding ground for the larger fishes, for these lakes contain a more abundant food supply per acre than does the river, and the heaviest catches of fish are obtained in sections where relative lake area is greatest.

(8) Changes in the aquatic organisms and their environment in the Illinois River as a result of the flood of Chicago sewage, rise in levels of the river, and restriction of the water between levees

A study by Professor Forbes and Mr. Richardson recounts briefly the changes in the biological conditions of the Illinois River as observed by them in studies carried on at various times from 1899 to 1919.¹⁰

The principal causes of change are: (a) Opening of the Chicago Drainage Canal in 1900; (b) great increase in the amount of Chicago sewage emptied into the Illinois River; and (c) extensive reclamation of river bottoms for agricultural purposes.

Sixteen changes are enumerated. The more important are as follows:

1. The opening of the drainage canal, with the consequent pumpage of water from Lake Michigan, practically doubled the amount of average flow in the Illinois River as measured at Peoria, and the previous low-water average was augmented by about 500 per cent, but the addition was relatively slight when water was very high. Thus the ratio of river water to canal water was varied from 1:5 during low water to over 9:1 during the times of highest water. The length of time included by the overflow period is materially increased, but

¹⁰ Some Recent Changes in Illinois River Biology. By S. A. Forbes and R. E. Richardson. Bulletin Illinois Natural History Survey, Vol. XIII, Art. VI (1919).

the area finally covered is only slightly increased. The average water level at Havana, 173 miles below mouth of the drainage canal, is raised nearly 3 feet by the opening of the canal.

2. The greater volume of water has naturally increased the depth and area of bottom-land lakes and backwater areas. One such area (Thompson Lake) was found to be increased two and one-half times in extent.

3. The increased depth of water has narrowed the belt of shallow woody water along banks of both river and backwaters, and inundated low-lying areas where shrubs and even trees formerly grew, resulting in their death, as attested by the present array of dead trees and snags protruding from the water.

4. The greater depth of water will not respond so readily to the heat of the sun, the net result being that temperature range is restricted. This must necessarily retard to some extent the decomposition processes and the chemical action which transform sewage materials into available food for plants and animals.

5. The increased volume of water increases the rate of flow. The time period now required for passage of water over a given distance is about one-half that required before opening of the canal. Decomposition processes are thus extended farther downstream, and sewage materials will flow about twice as far downstream before being properly purified. In effect, the river has been shortened by about one-half.

6. The sewage load of the river has greatly increased since 1899, due to the turning of Chicago sewage in the Des Plaines River. However, due to the large volume of lake water used to flush this sewage through the canal, the actual percentage of sewage in the augmented stream (the Illinois River) is less, because of the high dilution. (This statement written in 1919.)

7. The effect of tributary waters, as the Fox River, or of local wastes, as sewage at Peoria, is now lessened, on account of the greater volume of water to be affected.

8. On account of increased speed of current, the organic contents of the sewage must traverse a greater distance before they are in suitable condition to be appropriated by certain animals and plants; consequently such animals and plants are in effect excluded by lack of suitable food from a greater portion of the upper river than was formerly the case. They have, in effect, been pushed farther downstream.

9. The ratio of total nitrogen escaping into the Mississippi River is now greater than in 1899—previous to opening of the sanitary canal. Specifically, it was about three and five-tenths to four and eight-tenths times as great in 1914 as in 1899. At the river's mouth the nitrates were, in parts per million, as 1 in 1899 to 1.45 in 1914. The nitrates likewise increased, in 1914, in the middle course of the Illinois—at Havana by 45 per cent, at Beardstown by 39 per cent, and at Meredosia by 40 per cent.

10. This greater food supply eventually results in greater production of plant and animal life. The average production of plankton at Havana in 1895-1898 was surpassed in 1909-10 by 135 per cent. The increase in one bottom-land lake examined was still greater. The collections of 1909-10 were made when only 25,000 acres of bottom land were under levee, whereas this area has now (1919) been increased about sixfold. This reclaiming of bottom lands will operate to decrease the plankton yield.

11. Reclamation of bottom lands for agricultural purposes has increased between 1899 and 1915 from 6,700 acres to over 200,000 acres. This will reduce the area subject to overflow every spring by 40 to 50 per cent, the river will rise higher in times of flood, and the flood waters, no longer able to spread out over adjacent low areas, will run off rapidly. The accelerated movement will

to some extent remove bottom sediments. The successive stages of oxidation of sewage materials will be carried farther downstream, organisms will continue a shorter time in the Illinois, and more of the food material of this river will escape unconsumed into the Mississippi.

12. Effects on the fisheries: In 1913 fish were practically driven out as far down the river as Ottawa (34 miles below sanitary canal). A normal population of fish was found about 77 to 93 miles downstream, just above Chillicothe. During 1900 to 1908 the fish yield of the lower river materially increased, due largely to the great multiplication of carp. The yield of fish decreased 1908 to 1914.

13. Fish differ with respect to their ability to withstand pollution of water by sewage. Those most sensitive to pollution will be the first to disappear from the upper river as pollution increases and the last to reappear as one goes downstream. In a catch of 79 fish at Ottawa (34 miles below mouth of sanitary canal) taken in 1911 or 1912, 69 were "shiners," a small fish very tolerant of sewage pollution.

14. The yield of fish diminished in the lower river 1908 to 1914 in spite of a large increase in materials for their food supply. This is explained by the fact that reclamation of bottom lands for agricultural purposes meanwhile increased from about 55,000 acres to nearly 200,000 acres. The loss to the river of such a large acreage¹¹ of backwater areas with consequent narrowing of the river channel and acceleration of its current means: (1) Lack of time for the adequate transformation of the raw organic matter into plant and animal forms suitable for fish food; (2) lack of time and of quiet environment for the breeding of fish and for refuge of the young until these are sufficiently developed to cope successfully with the dangers of the river channel.

(9) Changes in small bottom and shore fauna of the Illinois River traceable to the encroachment of excess sewage pollution from Chicago 16 miles per year downstream

In 1920 Mr. R. E. Richardson, who has most thorough knowledge of the biological history and present status of the Illinois River system, made an investigation¹² with a view to recording such biological changes as had developed since his detailed study of the river in 1913-1915. That certain changes might be expected was indicated by the fact that since 1910, (1) Chicago had increased materially in population (about 20 per cent), and (2) stockyard activities there had increased by about 50 per cent, with proportionate increase in Chicago sewage and industrial waste, poured into the Illinois River by way of the drainage canal and the Des Plaines River. Meantime (3) reclamation operations were reducing the available overflow area of the river so that the water, bearing a heavily increased load of sewage, was further confined within levees which increased its current and thus carried the burden of organic matter much farther downstream before the reducing agencies of nature had sufficient time to act.

¹¹ About 36 per cent of the total acreage of bottom-land lakes had already been reclaimed in 1915, thus excluding those lakes from fish breeding. Report by Alvord and Burdick on Illinois River and Its Bottom Lands, p. 14.

¹² Changes in the Bottom and Shore Fauna of the Middle Illinois River and Its Connecting Lakes Since 1913-1915 as a Result of the Increase, Southward, of Sewage Pollution. By Robert E. Richardson, 1920. Bull. U. S. Nat. Hist. Survey, Vol. XIV, Art. IV.

During July, August, and September, 1920, examinations were made at 71 stations in Peoria Lake and the narrower river extending to a point 8 miles below Havana (comprising about 69 miles of river length) and at 25 stations in five of the adjacent lakes (connecting with the river) near Havana.

The net results of this study show that there have been sweeping reductions in small bottom fauna, obliteration of certain families, and increase of new pollutional forms since 1915. The pollution zone has encroached 80 miles farther downstream (see 3, par. 1, above) or 16 miles per year for the 5-year period. More specifically:

(1) At the head of the expansion of the river known as Peoria Lake (at which point the sewage of Chicago had flowed 38 miles through the drainage canal, 16 miles by way of Des Plaines River and 92 miles in the Illinois River, 146 miles in all below Lake Michigan) most of the mollusks, abundant in 1915, had disappeared (12 species, of 16 present in 1915, had disappeared), midge larvae and sludge worms had increased enormously and the formerly numerous insect larvae, together with related forms, had practically disappeared. There remained only a negligible trace of the former heavy growth of aquatic plants. The bottom muds moreover were characterized by a vile odor and gaseous condition that was not present in 1915.

(2) In the 8-mile section of river next above Havana, and 109 miles below Lake Michigan, bottom fauna had decreased in volume and changed in character. The yield of over 5,000 pounds per acre in 1915 decreased to 250 pounds per acre in 1920. Five of the seven families of snails had disappeared in 1920, as had also six species of midge larvae. Sludge worms, absent in 1915, had appeared, and insect larvae and related organisms were present only in greatly reduced numbers. The wholesome earthy odor of bottom mud observed in 1915 was replaced, in 1920, by foul odors, with septic bubbling taking place during hot weather.

(3) A 6-mile section of river beginning 2 miles below Havana and 209 miles below Lake Michigan was characterized by swifter current, less sedimentation, and harder bottom than was possessed by the section above Havana. Physical condition of the mud was fairly good; and though insect larvae were present in nearly normal numbers, with mollusks in moderate numbers, yet there was very noticeable decrease in the latter, eight species having disappeared since 1915. Also a few sludge worms had invaded this portion of the river since the 1915 examination.

(4) Four bottom-land lakes connected with the river and located near Havana showed in 1920 practical disappearance of the snail fauna, similar loss of insect larvae and related organisms, a mere remnant of the rich aquatic vegetation that had covered 30 to 50 per cent of the lakes area in 1915, and almost total loss of the very

rich weed fauna (2,000 pounds per acre in 1915) incident to this aquatic vegetation, this fauna constituting the chief factor in the food of fish of commercial value which were likewise abundant in these lakes in 1915.

(5) A careful estimate of the changed conditions as stated above indicates that since 1915 over 34,000,000 pounds loss—over 90 per cent—has been sustained in the stocks of bottom and weed fauna in the 103-mile stretch of river and lakes areas between Chillicothe and La Grange. This is a potential fish yield of about 7,000,000 pounds (estimating that 5 pounds of fish food yields a pound increase in weight of fish) and this loss in fish yield must be placed in the debit column of a river whose fisheries were a few years ago among the richest of the fresh-water stream fisheries of the world.

(10) Increasing variety of sewage-tolerant organisms suggests improvement in a polluted environment in which, during six or seven years, practically all organisms except these very tolerant ones have died out

Richardson again¹¹ studied the bottom fauna of Peoria Lake in 1922, basing his conclusions on quantitative bottom dredgings from 71 stations distributed in both the channel and the wide waters of the lake, and covering a linear distance of about 20 miles. In summarizing this work, he says, in substance:

1. Improvement in conditions since 1920 is indicated by the presence of nearly twice as many species of bottom organisms, the chief increase being largely confined to "tolerant sphaeriid snails."

2. This increase of the sphaeriidae was correlated with large expansion in the Packingtown slaughterings at Chicago, and with great increase in numbers of tubificid worms in the muds of the upper lake and river at Chillicothe. A possible progressive immunisation of the tolerant snails is suggested.

3. Improvement in the muds is indicated by increase in variety of organisms (1) as sampling proceeds downstream, (2) as sampling proceeds from mid-channel into the adjacent wide waters of the lake.

4. In the lower lake there is evidence of mixed conditions on the bottom, apparently due chiefly (1) to wind-blown local pollution, (2) to the greater current in the lower lake channel.

5. "Species that have definitely disappeared from Peoria Lake since 1913-1915 include all but three or four kinds out of a total of more than 40 kinds of fresh-water mussels; all the snails of the family Amnicolidae; all but one species of the formerly important * * * snail family Viviparidae; and a varied weed fauna."

6. Large lists of bottom invertebrates (numbering about 70 species) were found in the region of Havana in 1913-1915. Relatively small lists (about 12 species) were meantime found in Peoria Lake, and most of these have since disappeared. This suggests that, prior to 1915, Peoria Lake may have suffered injury from upriver pollution.

¹¹ Changes in the Small Bottom Fauna of Peoria Lake, 1920 to 1922, by Robert E. Richardson. Natural History Survey (Illinois) Bulletin XV, Art. V.

¹² Richardson uses the term "tolerant" in preference to "contaminants," as the former word affords greater flexibility of meaning and also greater suitability of application to the animals themselves.

- (11) Bottom organisms tend to show, by their index value, the progressive and harmful effects of pollution by the practical extinction of the cleaner organisms (suitable for fish food) and heavy increase meantime of unsuitable pollutional forms—Great care and adequate study are necessary, in each situation, for the proper appraisal of this index value

A paper¹² of unusual biological significance was published by Richardson in 1928, summarizing the outstanding results of certain previous studies on the Illinois River, together with data obtained during 1924 and 1925. Having had part in various studies on this river during a period of more than 20 years, and having acquired an intimate knowledge of the interplay of the numerous factors that affect these waters, Mr. Richardson knows the river in all its moods, so to speak, and writes with the authority and mature judgment warranted by an immense amount of basic data collected during these many years of careful study, much of the time having been spent in a floating laboratory on the river itself.

Following is a partial summary of outstanding items in the above paper:

1. Basic data concerned in this paper were obtained from 1,308 biological collections made 1913 to 1925, inclusive, over a 225-mile stretch of the Illinois River and its bottom-land lakes.
2. The upper part of the river is heavily polluted by sewage from Chicago and waste from the stockyards. Effects of this pollution diminish slowly downstream. Moderate amounts of sewage and industrial waste are added at points downstream, particularly at Peoria and Pekin.
3. "An effort is made to distinguish septic, pollutional, subpollutional, and clean-water conditions by the plant and animal species characteristic of each and from these to select an index series of species whose abundance marks the grade of pollution in which each predominates; but this classification of degrees of pollution is difficult because the several divisions fade into each other gradually with no well-marked boundaries and different grades intermingle in the same locality, those of the main current of the stream differing from those dominating in comparatively sluggish, shallow and weedy marginal waters; and these differing again from those of still more sluggish, broad expanses of shallow water." In the river channel, samples taken from the water and from the bottom sediments often yield organisms differing both in abundance and in sensitivity. It is recommended that chemical data supplement a comprehensive study of the dominant organisms in each situation, in order to obtain a dependable classification of these relative to the degree of pollution of the water.
4. Between 1913 and 1920 the increase in pollution caused clean-water conditions to recede downstream about 8 miles a year. There was heavy decrease in number of species represented in the bottom fauna in Peoria Lake and even in the lower river below Havana. Certain species characteristic of clean water disappeared entirely from Peoria Lake, and in the 49 miles of river next below they diminished from 49 species to 3, and in the next 31 miles from 17 species to 6. Meantime pollutional species increased over these same sections of river. Promi-

¹² The Bottom Fauna of the Middle Illinois River, 1913-1925. Its Distribution, Abundance, Value, etc., and Index Value in the Study of Stream Pollution. Illinois Natural History Survey Bulletin XVII, Article XII.

nent among the latter were tubificid worms. Where these numbered only 16 per square yard in 1915, they numbered 2,463 per square yard in 1920.

5. Prolonged floods in 1924 apparently distributed large quantities of up-the-river sludge in Peoria Lake and below. There resulted an enormous increase of tubificid worms, midge larvae, and of a small sewage-tolerant bivalve mollusk. The latter, averaging four-fifths or more of the catch in Peoria Lake bottom samples, was more than twenty times as abundant as in 1920.

6. Under clean-water conditions snails tend to dominate and to appropriate the greater portion of the available food supply. Smaller bivalve mollusks (*Sphaeriidae*) are thereby suppressed, by reason of insufficient food, and the sucker-mouth fishes (carp, buffalo cat, etc.) that depend largely on these mollusks for food are in turn depleted, as these fish do not usually feed upon the larger snails. If, on the other hand, there is sufficient pollution to prevent the multiplication of these larger, clean-water snails, an adequate food supply is thereby left available to the small bivalve mollusks (which are tolerant of sewage pollution). These multiply, and such fish as carp and buffalo cat will in turn find adequate food supply. But this degree of pollution sufficient to kill off the cleaner snails also tends to produce a gassy taste, and a diseased condition in as many as 50 per cent of the now abundant carp, thus diminishing the market value of these fish when obtained from the polluted Illinois River.

7. The lag of small bottom animals behind the dissolved oxygen appears to be due to two causes; (1) The naturally slow rate of respread upstream of cleaner-water forms, as against the easier downstream movement of the pollutional and unusually tolerant bottom species; and (2) the delivery with every flood (into territory that would otherwise remain reasonably clean) of fresh loads of incompletely oxidized organic sediment.

CHAPTER III

PHYSIOGRAPHIC AND POLLUTIONAL FEATURES OF THE ILLINOIS RIVER

The Illinois River¹ is formed by the union of the Des Plaines and the Kankakee Rivers, about 12 miles below Joliet, Ill. The main stream thus formed flows almost directly west for 62 miles, then southwest for 211 miles to unite with the Mississippi about 20 miles above the mouth of the Missouri River. The first 41 miles of its course (beginning at the junction) exhibits a series of rock channels, separated by pools, the whole forming a rapid descent with a fall per mile varying from nearly 6 inches in the pool stretches to about 46 inches in the rapids stretches. The lower Illinois, comprising 223 miles of its total length, meantime has a total fall of only 33 feet, or an average of about 1.8 inch per mile.

All the tributaries of the Illinois¹ are relatively small. There are, however, nine which have watersheds of approximately 1,000 square miles or over. The largest of these are the Kankakee, with drainage area of 5,297 square miles; the Fox, with 2,580 square miles; the Sangamon, with 5,332 square miles; and the Spock, with 1,812 square miles.

¹ In the stretch from Joliet (12 miles up the Des Plaines branch) to La Salle, 59 miles, the average fall is 18 inches per mile. Below La Salle the slope flattens to less than 1 inch per mile for 60 miles (to Peoria), while from Peoria to the mouth of the river, 165 miles, the average fall is about 1.43 inches per mile. The upper portion of the river is therefore quite turbulent, but the lower reaches are relatively quiet, to such an extent that much suspended matter is deposited in the lower river.

In the speedy purification of sewage in the waters of a stream, thorough mixing of sewage and water is a matter of primary importance partly for dilution purposes and partly for aeration, which, effected by the turbulence, streaming, and turnover incident to thorough mixing, will enable oxygen-using organisms to attack the organic matter with vigor.

On entering the Des Plaines River the lake water and sewage mixture is further diluted slightly by this small stream which meantime heavily seeds the water with organisms from its own heavily polluted, but well-stabilized, waters, so these organisms, beginning to

¹ Condensed from P. H. Bull. 171, pp. 4 to 8.

die out in the Des Plaines for want of food, find themselves suddenly placed in a new and much larger field of work. Now follows an 8-mile course during which the waters fall about 50 feet, including a 12-foot fall over the Jackson Street Dam in Joliet. There is continuous turbulence and turnover in the swift current which now prevails, compelling the most thorough mixture and much aeration of the combined sewage from the canal and water from the Des Plaines. Thus the initial act in the natural purification of the Illinois River is well done. The importance of this initial mixing may be better understood when it is noted that the advent of a tributary below this turbulent Joliet section is not attended by thorough mingling of the waters until several miles have been covered. Forbes and Richardson² (1913) note at Morris the imperfect mingling of the waters of the Kankakee and the Des Plaines 10 miles below their junction, and to some extent at Marseilles, 25 miles below. Such imperfect mingling of polluted with unpolluted water must necessarily delay the purification of the stream as a whole.

A physical feature of importance is "Peoria Lake" (just above Peoria) where the river widens 1 to 2 miles. This section is about 18 miles long, with a maximum low-water depth of 20 feet in the channel. Much of the expanded portion (especially south of the channel) is 6 to 10 feet deep. This water body furnishes a place for expansion of the stream at times of rising levels; consequently a period of storage for such water as thus departs from the channel proper, and later a supply reservoir of such stored water when water levels are falling and this lake water is returned to the channel. Moreover, the material reduction in speed of current when the water reaches this lake results in the deposition of a large amount of suspended matter as sediment. The water on leaving the lake has thus been subjected to an intensive treatment, so to speak, on the part of physical, chemical, and biological agencies, in that it has, since entering the lake, (a) deposited a portion of its suspended matter; (b) mingled to some extent with the water already in the lake; (c) spread out over a relatively larger surface than was possible in the deeper river channel, thus increasing aeration; (d) acquired more heat from the sun in summer or has been subject to greater cold in winter; (e) had favorable conditions of light, temperature, and quiet for the growth of algæ and other aquatic life, including plankton; (f) benefited, presumably, because such growth has utilized a portion of its dissolved organic matter; and (g) increased its content of dissolved oxygen by reason of the photosynthetic activity of plant growth. Thus, from the physical point of view, this lake functions as a stabilizer, while from the biological point of view it is an accelerator.

² Some recent changes in Illinois River Biology. Forbes and Richardson, 1919, p. 142.

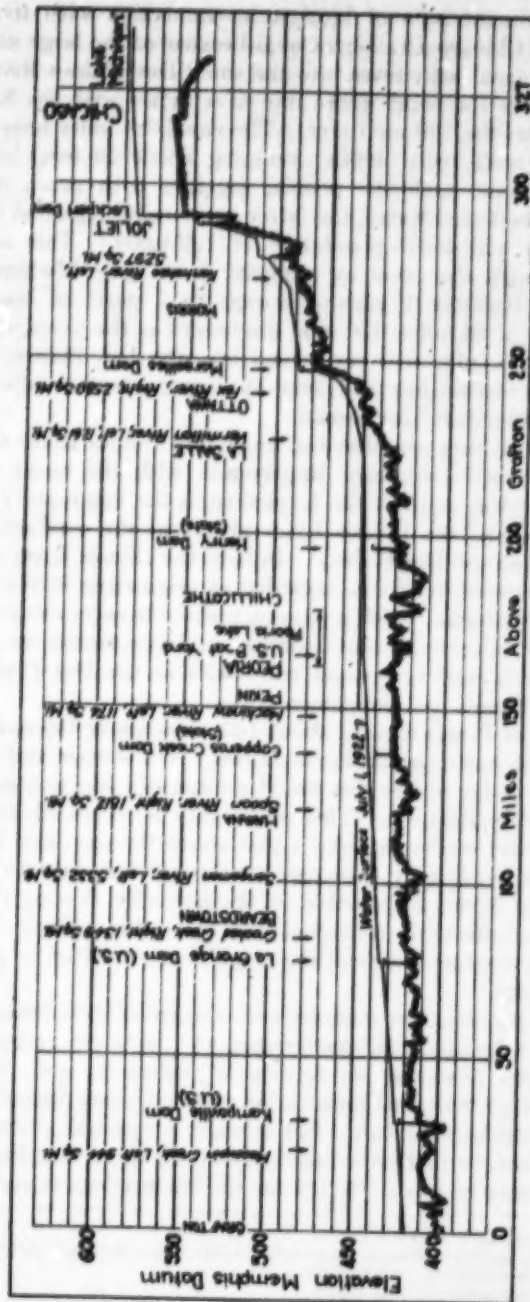


FIGURE 2.—Profile of the Illinois River and the Chicago Drainage Canal

The paramount item of interest in connection with the Illinois River is the Chicago Drainage Canal because of the large amount of sewage this canal introduces into the small Des Plaines River about 15 miles above the point where this river unites with the Kankakee River to form the Illinois River. The canal, 28 miles long and 160 to 200 feet wide, with depth averaging about 26 feet, brings the sewage of about 3,000,000 people, together with much industrial waste and stockyard waste, the latter items being regarded as equivalent to an additional population of 1,691,000.³ This sewage is flushed through the canal by pumpage from Lake Michigan, there being approximately 1 part of sewage to 7 parts of lake water.⁴ After a flow of 28 miles the canal discharges at the average monthly rate of 8,650⁵ cubic feet per second into the Des Plaines River at Joliet which stream has meantime an average monthly discharge of about 532 cubic feet⁶ per second.

It is at once apparent that the small Des Plaines River assumes a greatly increased volumetric importance, with the result that this augmented river, and not the Kankakee, is the dominating factor in the formation of the Illinois River proper at the confluence of the Kankakee and the Des Plaines. In fact, the Illinois River, volumetrically considered, might be regarded as originating in the pumpage from Lake Michigan, which pumpage, utilized to carry away Chicago's sewage and industrial waste is diluted and augmented somewhat en route by such relatively small tributaries as the Des Plaines, Fox, Kankakee, Spoon, and Sangamon Rivers.

The city of Peoria located about 163 miles above the outlet of the Illinois River has a population of 76,000. The sewage and industrial waste from a city of this size would presumably function as a source of appreciable pollution. This probability is increased by the fact that the outlet of Peoria Lake is just above the city, and the water, presumably purified by slow passage through this lake to a greater degree than would be possible in the normally flowing current, is likely to be sufficiently recovered from the initial pollution to reflect a secondary contamination of the magnitude presented by the wastes of such a city.

The various sampling stations were chosen in accordance with the foregoing outstanding characteristics of the river relative to its physiographic features, its sources of pollution, and its natural mechanism for biological purification after pollution, namely, mixing, aeration, exposure to light, and storage, or partial storage, of the flowing water, as in Peoria Lake. Many of these sampling stations were the same as those selected for the bacteriological and chemical

³ Public Health Bulletin 171, Table 12, p. 24.

⁴ Report of the Engineering Board of Review of the Sanitary District of Chicago, Part II, p. 37.

⁵ Public Health Bulletin 171, Table 16, p. 42.

⁶ Public Health Bulletin 171, Table 16, p. 32.

samples collected at the same time⁷ but were less numerous, inasmuch as plankton life in general has a longer tenure of life than do bacteria, and the significant changes in the plankton population of a stream may ordinarily be adequately followed by weekly samples taken at a given station, or by monthly samples of bottom sediments, whose population of worms, insect larvae, mollusks, etc., ordinarily lives several weeks, or even months. The stations selected for biological samples, together with a brief statement as to the probable significance of each station thus selected, will be found in the appended Table 2. The number designating each sampling station indicates its location in number of miles above the mouth of the Illinois River.

TABLE NO. 1.—Summary of biological collections and field visits, Illinois River investigation, 1921-22

Station	Period of examination	Number and kind of samples						Field visits
		Plankton samples		Bottom sediments	Algae, floating life, etc.	Surface films	Total samples	
		Mid depth	Surface					
292.....	From September, 1921, to Aug. 31, 1922.....	49	0	8	12	0	69	9
Des Plaines River.....	From Sept. 21, 1921, to Aug. 31, 1922.....	49	0	0	47	0	96	9
280.....	do.....	49	0	2	29	0	77	8
286.....	do.....	49	0	12	64	0	125	9
283.....	do.....	48	0	0	0	0	48	0
Kankakee River.....	do.....	48	0	0	0	0	48	0
Ottawa (280).....	June 23, 1921 to Aug. 10, 1921.....	8	2	2	2	0	14	1
Fox River.....	June 23, 1921, to July 27, 1921.....	6	0	0	1	0	7	1
Vermilion River.....	June 23, 1921, to Aug. 10, 1921.....	10	6	2	0	1	19	2
LaSalle (280).....	June 23, 1921, to Aug. 31, 1922.....	60	14	6	28	3	109	3
186.....	Mar. 22, 1922, to Aug. 31, 1922.....	42	0	0	0	0	42	0
179.....	June 21, 1921, to Aug. 31, 1922.....	121	113	36	47	0	317	13
Monrovia.....	Aug. 30, 1921, to Nov. 26, 1921.....	25	25	6	2	0	58	2
166.....	June 21, 1921, to Aug. 31, 1922.....	115	4	0	0	0	119	0
163.....	June 21, 1921, to Aug. 3, 1921.....	9	4	0	0	0	13	0
165.....	June 30, 1921, to Aug. 17, 1921.....	9	0	7	0	0	16	2
do.....	do.....	8	3	3	0	0	14	3
Mackinaw.....	June 15, 1921, to Aug. 17, 1921.....	9	6	0	0	1	16	1
123.....	June 10, 1921, to Aug. 31, 1922.....	62	50	31	4	0	156	12
Spoon River.....	do.....	62	66	12	0	2	144	12
100.....	June 12, 1921, to Nov. 12, 1921.....	21	8	14	1	2	48	2
Sangamon River.....	do.....	22	19	9	0	4	54	3
Crooked Creek.....	June 11, 1921, to Sept. 14, 1921.....	16	10	1	0	0	27	1
Macoupin Creek.....	June 20, 1921, to Aug. 9, 1921.....	8	8	3	0	3	21	1
25.....	June 12, 1921, to Aug. 31, 1922.....	60	0	48	2	1	107	8
Other points.....	do.....	26	0	12	2	0	41	3
Total.....	.....	961	340	206	235	15	1,796	108

⁶ Samples discontinued in a few weeks.

⁷ The report based on study of the bacteriological and the chemical samples is published as Public Health Bulletin No. 171 (1927).

30 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE NO. 2—*Biological sampling stations*

Station	Location	Biological significance
281.....	Drainage canal at 18th St., Lockport.	The organism content of water, and of bottom sediments, in the Chicago Drainage Canal before its junction with the Des Plaines River.
Des Plaines River (282).....	At 18th St., Lockport.	The organism content of the polluted but partly uncovered Des Plaines River prior to its receiving the canal water. To note what organisms would thus be added into the canal water.
283.....	Just above the Jackson St. Dam, Joliet.	Plankton content, and life in bottom sediments, prior to passage over the dam and through 2 miles of turbulent, rapid water to station 284.
284.....	At Brandon Bridge, below Joliet.	After 2 miles of very turbulent flow and thorough mixing of the combined canal and Des Plaines water. The organism content that would respond to, or persist in the (1) highly polluted, and (2) very turbulent stream, and thus seed the succeeding portions of the stream.
Kankakee River (272).....	16 miles below the junction of the canal with the Des Plaines River.	The plankton content contributed to the polluted main stream by this relatively unpolluted stream—the largest tributary of the upper Illinois River.
285.....	Morris.	The plankton content 25 miles below, and 15 hours after, the confluence and thorough mixing of canal sewage and Des Plaines water, the possible influence of the Kankakee River, and the plankton content available to carry on the biological work.
287.....	La Salle.	The possible progress of biological purification as indicated by kinds and abundance of certain plankton organisms, and condition of the bottom sediments, as the water approaches that section of the stream, some miles below, where its odor disappears and its color becomes natural.
186.....	Henry.	The kinds and relative abundance of plankton organisms in water which, 20 miles above, is grayish and has sewage odor, but 17 miles below (at 176) is clear and without odor.
176.....	Chillicothe at head of Peoria Lake.	The plankton content and bottom conditions in a water which 126 hours previously and 116 miles upstream, was grossly polluted, grayish in color, and with sewage odor, but is now clear, without odor, and looks clean. Also to compare with plankton content of upper river stations.
168.....	Just above Peoria and at foot of Peoria Lake.	To compare with data of station 176, at head of lake and to ascertain the net effect of the lake as shown (1) in amount and kinds of plankton organisms, and (2) in progress of purification as indicated by these organisms.
122.....	Just above Havana.	To note any apparent progress of purification as indicated by the plankton content, and the condition and population of bottom sediments. Also any apparent effect of sewage and industrial wastes from the city of Peoria.
The Spoon River.....	Opposite Havana.	The present plankton contribution of this small, unpolluted, but sluggish stream, which, in Kohde's study (1882-1883) was not sluggish but was plankton-poor. To note also the condition and population of bottom sediments.
160.....	Just above mouth of the Sangamon River.	The prevailing plankton content, and condition of the bottom sediments, relative to the progressing purification which seems apparent in all the lower river.
Sangamon.....	50 miles above mouth of the Illinois River.	The largest tributary of the lower Illinois. Polluted by the sewage of Springfield, Ill., located on the Sangamon, 63 miles above its confluence with the Illinois River. Information was desired as to plankton content thus contributed to the Illinois River.
26.....	Below Kampsville, Ill., and 26 miles above the mouth of the Illinois River.	To note the plankton content, the bottom conditions, and the possible indications of progressive and effective purification at this lowermost station of the Illinois River, as compared to the plankton content, the bottom conditions, and the degree of purification apparently indicated at the several sampling stations previously enumerated.

* This statement refers to conditions in 1921-1922.

CHAPTER IV

THE PRESENT STUDY, ITS OBJECT, SCOPE, AND LIMITATIONS

The chief object of the biological study was: (1) To ascertain the distinctive features in the biology of successive zones; (2) to relate the biological findings to other facts bearing upon pollution, i. e., time and distance factors, concentration of sewage, physical conditions in channel, etc.; and (3) to seek a better understanding of the ecology of such plankton forms as are usually found in polluted water.

In addition, a deep scientific interest attaches also, by reason of the previous investigations and the results thereof, which are stated in some detail in the abstracts given in preceding pages. It may here be stated that Kofoid's study of the unpolluted stream, completed more than two decades ago; the flood of Chicago sewage beginning in 1900; the apparently satisfactory disposal of this sewage as shown by Forbes and Richardson's studies in 1913; similar study in 1915 by Richardson showing marvelous yield of small bottom fauna; the significant discovery by the same worker in 1920 that these valuable sources of fish food were being killed by rapid encroachment of the pollution zone downstream; the great increase in amount of sewage and wastes from Chicago; and meantime the restriction of lower river waters by levees constructed in extensive reclamation projects—all these are successive events and interrelated stages in the biological history of a stream of well-known economic importance. The present study essays to add another chapter to this series of biological records of one of our great rivers which, serving man to its utmost, may yet become a victim to excessive or unreasonable demands which arise, let us say, from a lack of knowledge of the real danger.

For this study we have collected plankton, bottom sediments, and certain other samples along practically the entire length of the river for a period of about one year, and have spent much time in field observations, practically every month of the year being represented in the field work.

The term "plankton" is, by definition, limited to the assemblage of minute microscopic plants and animals which are free swimming or floating, and are therefore carried about by any movement of the water. As a matter of fact, however, there are many minute animals and plants which are attached to some object in the water, and are thus not moved about by currents. Such organisms belong to

that particular environment as truly as do the similar organisms that are swimming or floating. It is evident that both classes secure their food supplies from the same water, and that their activities may affect its condition in similar fashion. In like manner, it is difficult or impossible, to establish a fixed limit to the work of the organisms of microscopic size on the one hand—the plankton—and that of the host of small worms, insect larvæ, bugs, beetles, mollusks and crustaceans, all of varying sizes (but larger than the plankton) which swim in the same water, or cling to submerged plants and stones, or burrow in the bottom mud. All these organisms, bona fide residents of a given aquatic community, are necessarily factors of more or less importance in the economy of the stream. An adequate study of the biology of this stream must therefore include, with the plankton, these associated organisms for such consideration as their activities or their numbers may seem to warrant. However, no attempt has been made to include fish in the present study except to record their occasional presence as noted during field trips.

It is humanly impossible within reasonable limits of time and space, to give detailed study to all of the many types of aquatic life encountered in a given water, especially if there be numerous sampling points, and seasonal fluctuations be taken into consideration by distributing the taking of samples over the various months of the year. On the other hand, a single sample, or a very few samples, will give no adequate data on which to base judgment of a changeable medium such as water. Experience has shown that succeeding samples of any kind may differ by a considerable margin. Our only remedy is a large number of samples whose average data will iron out the individual differences. Similarly, there are wide differences due to seasonal fluctuations. Our remedy here is not only a large number of samples—but also proper distribution of these so as to show at least a year's régime. Qualitatively speaking, plankton samples are of greater value as a basis of judgment when studied in connection with associated organisms; by the same token, the basis for final judgment must necessarily depend on the careful correlation of all available evidence, bacteriological, biological, chemical, and physical.

The samples for this study were taken continuously for a period of 14 months,¹ thus affording adequate data concerning seasonal fluctuations. Plankton samples were taken weekly, bottom sediments monthly, and samples of algæ, larger plants, etc., in season, or whenever found by the biologist in his monthly field trips. Moreover, these biological samples covered practically the entire length of the

¹ Except in the Joliet section, where only 11 months were covered.

river, from the Des Plaines River and sanitary canal at Lockport to the lower Illinois River within 25 miles of its mouth at Grafton.

The samples were confined to the river proper and a few of the larger tributaries. The numerous adjacent bottom-land lakes and backwaters which formerly characterized the lower 100 miles of the river's course—and some of which still remain—were not included in the biological schedule. The main reason for this apparent neglect of these usually important biological delay stations which function as breeding ground for plankton and related organisms, also as feeding and breeding grounds for many kinds of fish, lies in the fact that the object of study was the river as a whole—rather than its less important subsidiary parts. The former importance of these accessory portions of the Illinois River has been lessened considerably in recent years by the reclamation of low-lying areas—including some of these lakes—for agricultural purposes; and the construction of levees incident to this undertaking has to a great extent confined the waters to the river channel. Moreover, these adjacent water-areas contribute their waters to those of the channel proper only at times of falling levels, and are thus only intermittent tributaries at best, whereas tributary streams such as the Sangamon and the Spoon are continually adding their waters to the main stream and they thus function as constant factors.

Nevertheless these backwater areas—such as have thus far escaped the reclamation operations—are of great importance in the biology of the stream along whose course they occur—and the study of channel samples collected at times of falling levels must take into consideration the inevitable contribution of organisms, particularly plankton, from these impounded backwaters and the effect of this seeding of the channel waters. Original plans included a study of one of the largest of these backwaters, Thompson Lake near Havana, until it was learned that reclamation activities already begun would speedily eliminate this lake as a factor and would thus render such study comparatively valueless.

METHODS AND PROCEDURES

The data upon which this report is based are obtained from the systematic examination of (a) plankton samples, (b) samples of bottom sediment, and (c) supplementary samples. All samples were collected from fixed sampling points which are discussed on page 30. All samples were examined to ascertain their content of living organisms, exclusive of bacteria on the one hand and of fish (or animals of similar size) on the other. Also, an effort is made to ascertain the major activities of these various organisms, particularly their food habits, and the net results of their metabolic activities, and an attempt

is made to correlate these activities (as indicated by the relative abundance of certain organisms) with the sanitary status of the water.

PROCEDURE IN TAKING SAMPLES

Plankton.—In the narrow, turbulent upper river, and in the drainage canal, the sample was taken at midstream, and at mid-depth, by lowering the dissolved oxygen sampler to the required point. In the wider stream from station 179 downward, mid-depth samples were taken in similar manner, but at three different points in the cross section of the stream, each sample being placed in a separate bottle. The three sampling points were so located in the cross section that each represented the flow of a like volume of water, calculated after securing adequate data as to contour of bottom of stream, depth at various points, and speed of current. The three bottles of water constituted one plankton sample from a given station, and were taken or shipped to the laboratory without delay.

Samples of bottom sediments.—These were obtained by the use of a mushroom-shaped scoop, with a capacity of about 3 liters of mud. The scoop, attached to a 50-foot rope, was thrown overboard and dragged on the bottom for a distance of 5 or 6 feet. If the bottom was hard, or the sediments scarce, the length of this drag was increased to about 10 or even 15 feet. On raising the scoop of mud to the surface, one liter was taken by selecting representative portions of contents of the scoop. This liter of selected mud constituted the sample, and is the basis of the data given in this study. It will be noted that such a sample is qualitative, and approximately quantitative also.

After noting the color, the odor, and the consistency (that is, its condition as to being exceedingly soft, like thin mortar, or spongy, containing much gas, or sticky, like stiff mortar, or like clay, or granular, like sandy mortar, etc.) of this bottom mud, the sample was at once placed in a fine sieve (30 meshes to the inch) and washed out by a vigorous lateral and rotary movement while holding the sieve partly under water. In this manner the mud was washed through the sieve, but all detritus, trash, shells, and all organisms larger than a small *cyclops* were retained in the sieve. This catch from one liter of mud was then placed in bottles, formalin added to kill and preserve the contents, and the sample shipped to the laboratory for subsequent examination and study.

In the upper turbulent portion of the river (in the Joliet region) no sediments could be found except small amounts in the protection of an occasional eddy near the shore. Everything movable was swept out by the strong current. Repeated trials in the channel with the mud scoop resulted only in small amounts of material scraped from the large stones on the bottom, or in getting the scoop fast and spilling

any catch obtained in the efforts to dislodge the scoop. On one occasion we were fortunate in obtaining from about 12 feet of water at station 288 a pair of ice tongs that had evidently lain on the bottom for many months, or maybe for years. These tongs were heavily beplastered with stalked ciliates, thus giving valuable evidence of the conditions on the bottom of the river at this station.

In the Des Plaines River at Lockport the current was too swift to permit the accumulation of sediments on the stony bottom. However, a shallow by-pass afforded opportunity to obtain such organisms as were living under or attached to the bottom stones.

Supplementary samples.—Failing to get any but occasional samples of sediments in the Joliet section, collections were made regularly (monthly) of certain other material, particularly the masses of attached ciliates which grew in great abundance along the margins and on the bottom stones. This material was also being carried downstream in small detached masses at practically all seasons of the year, as was also the sewage fungus *Sphaerotilus* which was less abundant. Samples of this floating material were taken also. Certain algae and an occasional small fish (usually dead) were also collected in this section of the river. From other sections of the river, samples of water plants, algae, colonies of bryozoa, floating debris containing various kinds of organisms, or any other material that might yield information relative to the biology of the river, were collected whenever found, especially during the monthly trips of the biologist in charge of this phase of the work. Surface films, or the "water bloom," were collected intact on a common microscope slide which, enveloped with paper, was introduced under the film, the paper removed, and the exposed slide then brought up, in a horizontal position until the film was encountered, thus removing a portion of the film in its natural position.

LABORATORY PROCEDURE WITH COLLECTED SAMPLES

Plankton.—On arrival at the laboratory, these samples were at once dosed with sufficient formalin (40 per cent solution) to make the sample a 3 or 4 per cent solution, then set aside to settle. Some days or weeks later, at monthly intervals throughout the year, the accumulated samples were filtered in order to obtain the entire plankton content, together with such amorphous matter, silt, etc., as might be present. The following plan was found to be satisfactory:

(1) Hard pressed, smooth filters¹ 9 or 10 inches in diameter, are folded in "twin cones"² fashion and placed in a large-ribbed funnel, preferably of glass.

¹ Whatman filter paper No. 50 was found to be very satisfactory for this work.

² A filter folded in this manner affords the following advantages: (1) The entire surface is used in filtering; (2) every portion of the filtering surface may be washed down effectively; (3) there are no deep folds to harbor organisms or detritus.

(2) The supernatant liquid is carefully siphoned from the two or three bottles constituting the plankton sample. This must be done without disturbing the sediment in bottom of bottles.

(3) The filter is to be washed down frequently by a fine spray from a wash bottle.

(4) The material in the filter is removed to a small bottle and the sediment in bottoms of plankton bottles is added to this bottle also. This bottle then contains all the suspended matter and organisms that were in original plankton sample, and is known as the plankton catch.

(5) A label stating place and time of sampling and amount of water used is affixed to the plankton catch. This catch is now ready for examination.

Examination of plankton samples and statement of results.—The plankton sample is now accurately measured, preferably by use of a 25-cubic centimeter pipette, fitted with strong bulb. If necessary, 3 per cent formalin solution may be added to eliminate a fraction of a cubic centimeter, or to afford sufficient dilution to make examination possible, if sample be very turbid. The amount of catch in the bottle may now be recorded on the label.

After thorough but gentle shaking, 1 cubic centimeter of the contents of the bottle is placed in the counting cell, and the cover glass adjusted. Examination now proceeds, first with a low-power microscope, the entire cell being examined and the number and position of any large organisms noted. This preliminary examination may be termed the once-over or survey.

The cell is next placed on the stage of a microscope with higher magnifying power. Usually a 16-millimeter objective and a 4× ocular is used, the ocular containing a micrometer disk, designed by Professor Whipple, which, at a certain tube length, will facilitate quick measurement of minute objects in the counting cell.

The larger organisms located during the once-over are now examined and measured, the values in cubic standard units being recorded in the once-over column.

Five fields are next examined in detail, these being representative fields in various portions of the entire cell. In this examination the various organisms are identified, and are measured meantime, so that the recorded values are comparable as to volume. The amorphous matter and silt, etc., that may be in these five fields is likewise measured as to approximate volume and the results recorded.⁴

Results are expressed in terms of *cubic standard units*,⁵ (a cube whose edge is 20 microns long). These values are readily changed to parts

⁴ Data relative to amorphous matter and silt may be or may not be of value, depending on the local situation and on the nature and scope of the investigation.

⁵ See pp. 16-18, Public Health Bulletin No. 131, for further details.

per million by volume, by dividing by 125, and without further change this value may in turn be expressed, if desired, as cubic centimeters per cubic meter of water. For example, 875 cubic standard units equal 7 parts per million by volume. This may be stated as 7 cubic centimeters in 1 cubic meter of water.

Procedure with mud organisms.—The material obtained from 1 liter of mud as stated on page 34 is dumped into a quantity of water in a large glass dish or tray (a 9-inch moist chamber is excellent for this purpose) and the trash separated from the organisms. The latter are then tabulated as to number and kind, and placed in such separate containers as will facilitate further study and, if necessary, dissected for purposes of exact identification. Many of these collections are preserved as museum specimens illustrating the bottom life of a stream such as the particular one under investigation.

Subsequent procedure with these bottom organisms will depend on the make-up of the catch. The organisms may be few, or easily identified even if numerous, or relatively unimportant. Certain larvae in particular must be carefully identified because of their significance relative to the sanitary status of the water. Minute dissections may be required for such identification. Thus the catch from one bottom sample may be examined adequately in an hour, while another catch may require an entire week or more for its study.

The various organisms are tabulated and the number of each given. No attempt is made in the present study to place these variously sized organisms on a comparable volumetric basis. They are merely counted. The only approach to quantitative data lies in the fact that all these counts are based on the catch from a like quantity of bottom sediments—1 liter.

Examination of other samples.—Specimens of the attached ciliates, fungi, and algae from the margins of the turbulent upper river, and a variety of the larger plants and animals from various sections of the river as far down as station 25, were examined and in most cases identified.

TERMS AND THEIR MEANING

In expressing and discussing results of observations and examinations the following terms will be used: "Total plankton," meaning the entire catch of plants and animals, but exclusive of the amorphous matter and silt. "Index organisms," meaning those organisms that are definitely known to prefer a polluted habitat or to shun such environment. These are classed under the headings, "Pollutional" and "Cleaner," in Table 3. These index organisms do not include those that exhibit indifference to such conditions, nor do they include the large proportion of organisms whose reaction relative to pollution is at present unknown. "Pollutional organisms" means those that

flourish only in a heavily polluted water. This includes the two classes, "septic" and "pollutional" as given by Forbes and Richardson.⁶

"Cleaner" refers to those organisms that flourish in water which is only slightly polluted, or is relatively clean. This includes the classes "contaminate" and "clean" as given in the reference just cited. The terms "pollution" and "cleaner water" are likewise sometimes used to indicate the "preferred environment" of the organisms, rather than the organisms themselves. "Oxygen producers" refers to those organisms that contain chlorophyll or its equivalent, and are known to be plant-like in their life processes, thereby consuming in respiration a minimum of oxygen, but, during sunlight, giving off a great excess of oxygen by the process of assimilation or photosynthesis. This includes all plants except the fungi and the bacteria. It also includes such of the Mastigophora, or Flagellates, as contain chlorophyll. "Oxygen consumers" are those organisms that consume oxygen by respiration, but, lacking chlorophyll, they have no photosynthetic action, as plants have, do not require light, and do not produce oxygen. The fungi, and various animal forms such as rhizopods, colorless flagellates, the ciliates, the rotifers, crustacea, and minute worms, are thus classed as oxygen consumers. It should be borne in mind that plankton data necessarily can not include the various classes of bacteria, many of which are heavy consumers of oxygen.

All plankton values are stated in terms of "cubic standard units," a volume represented by a cube 20 microns on the edge. Very often several of the smaller organisms are required to make up a volume equal to one cubic standard unit. On the other hand, a single larger organism, such as a rotifer or a crustacean, may measure several hundred cubic standard units. Obviously the only way to put these organisms of all sizes on a comparable basis is to express their values in terms of volume. This has been done in all cases. The single word "unit" is frequently used for sake of brevity. Dividing the number of cubic standard units by 125 gives results in "parts per million by volume."

⁶ Bull. Ill. State Lab. Nat. Hist., Vol. IX, Art. X, 1913, p. 498.

CHAPTER V

SUMMARY OF FIELD OBSERVATIONS AND OF LABORATORY FINDINGS

Certain field observations are presented in Table 2, last column (see p. 30) and in the bottom sediment tables given in the summary by stations section, pages 55 to 185 inclusive. Basic data from weekly samples from the various stations for a period of over a year condensed to monthly averages for each station are given in this same section, in such tables as Nos. 9, 13, 17, etc. The same data are presented in Table 53 summarized by months.

Presentation of the results of weekly examinations is attempted in Table 54 in such a way as to present the essential qualitative and approximate quantitative make-up of the plankton. Monthly and seasonal averages from this table are given in such tables as 10, 14, 16, 20, etc., in the summary by stations section. Table 6 attempts to summarize the general plankton picture in broad terms of seasonal averages. Tables 50, 51, and 52 show for winter, for summer, and for the entire collecting period, respectively, the essential correlation between pollutional organisms of the plankton and the bacterial content of the water, these two classes of organisms tending to decrease in value as the water flows. The cleaner-water organisms of the plankton meantime increase in relative abundance.

The bottom-sediment tables, such as Nos. 11, 12, 15, 18, etc., constitute an attempt to tabulate certain items often overlooked in the study of a polluted stream; i. e., the apparent sanitary condition of the bottom, the margins, and the water surface, as indicated by physical conditions and by contained and prevalent organisms, particularly those of the bottom sediments. There is substantial and significant correlation between the known heavy pollution of the upper river and the malodorous sediments (where these are obtainable), the high content of tubificid worms, the absence of gill-breathing insect larvae, and the great abundance of colonial ciliates attached to bottom or marginal stones. In the lower reaches of the river, including Havana and Kampsville, there is similar correlation between the clean-looking, odorless water, apparently of good quality, and the sediments with little or no odor, the few tubificid worms, the relative abundance and variety of gill-breathing insect larvae, and the entire absence of colonial ciliates which are so abundant in the polluted upper river.

PHYSIOGRAPHIC

(References: Profile chart and Tables 2, 12, 15, 18, 25, 30, 35, 38, 43, and 46.)

(1) The Des Plaines River, from Lockport to Dresden Heights, 16 miles, is swift and turbulent. The upper 8 miles has an average declivity of $6\frac{1}{2}$ feet. The drainage canal, joining the river at Lockport, brings a very large volume of diluted sewage, many times as great as the discharge of the Des Plaines River itself at the point of union.

(2) This upper river constitutes an ideal natural mechanism to insure maximum biological activity later, in that (a) the large volume of recent sewage is subject to continuous turnover, mixing, and aeration in the fall of 52 feet in 8 miles. There is no possibility of the early formation of a great mass of decomposing sludge, with its attendant nuisance as would undoubtedly result if this amount of sewage were discharged into a slow stream; (b) this thoroughly mixed sewage is meantime effectively seeded from the Des Plaines River,¹ which functions as a source of suitable organisms for the large volume of prepared sewage.

(3) The ideal mixing in the extreme upper portion (the 8-mile Joliet section) is ably seconded by the succeeding 56-mile portion, with a drop of 66 feet, as far down as Utica, and, to some extent, as far as Chillicothe (an additional 51 miles) by the still rapid but gradually diminishing speed of the water which condition operates to deposit gradually and over a very large total area a portion of the heavy load of suspended organic matter, thus facilitating biological action, especially along the slower-flowing margins, and, in places, on the channel bottom. Retarded flow reaches its climax in Peoria Lake, an expanded portion of the river channel about 18 miles long and nearly a mile wide. Movement of water here, according to Richardson² is 0.59 mile per hour at flood stage,³ and only 0.29 mile per hour at low-water stage. Thus the vigorous but gradually decreasing mixing effected in the upper river is here succeeded by a period of comparative calm, while the water spreads over this large area and is meantime exposed to air and light in this shallow lake. Biological activity is favored by such an environment. The lower river, continuing 160 miles below Peoria Lake, pursues a comparatively straight course, the clean-looking water having an average velocity, during flood stage,³ of 1.58 miles per hour.

(4) The somewhat irregular flow of the drainage canal, due to its control for the purpose of producing light and power, produces essentially a high water at night, followed by lower levels during the day,

¹ "The Des Plaines was a seed bed, in short, and the canal water the soil, for the culture of sewage organisms in the Illinois." Forbes and Richardson, 1912, p. 503.

² Bulletin Illinois Natural History Survey, Vol. XIII, Art. XV, p. 376.

³ Gage 18 feet, Peoria.

in that section of the river immediately below the lower end of the canal. The high water at night covers marginal stones and low areas which during the day are drained, and exposed to air and sunlight. This regular sequence of "tidal" action makes possible on these marginal stones and adjacent mud areas a heavy growth of blue-green alga which would otherwise be present in scant amount only.

PHYSICAL EVIDENCE OF POLLUTION IN THE WATER

(References: Tables 11, 15, 18, 25, and 30)

(5) The pollution of the upper river is apparent to the casual observer as far downstream as La Salle, and below. (La Salle is 62 miles below the mouth of the drainage canal.) The pollution is indicated to the senses (a) by the odor of sewage; (b) by rather large amounts of dirty-looking masses floating, some of this arising, with many bubbles, from the bottom; (c) by the unnatural grayish color of the water. In the 48-mile stretch between La Salle and Chillicothe (station 179) a change occurs. At the last-named station, and below, to the mouth of the river, there is no sewage odor; floating material is comparatively small in amount, and the water has lost its grayish color. So far as the senses are concerned, this lower river seems to be clean, except for heavy turbidity at times.

(6) The water at Joliet, and as far downstream as La Salle (station 227) contains very large amounts of suspended matter in minute masses varying from microscopic size to that of a pea. Larger masses are also abundant, often attaining the approximate size of a walnut. These larger masses are chiefly fragments of colonies of the ciliates *Carchesium* and *Epistylis*, with frequent presence of the fungus forms *Sphaerotilus* and *Leptomitrus*. The small and microscopic masses are chiefly minute bits of the same colonies. These small fragments appear in the plankton and constitute the principal source of the *Carchesium* and *Epistylis* recorded in the plankton data. Margins and bottom in the Joliet section are apparently carpeted with whitish masses of these colonies, constituting the chief visible life of the polluted upper river.

(7) Floating rafts of unsightly material are fairly common at La Salle and farther downstream. These masses are of two kinds:

(a) So-called "sludge," dirty gray in color, and in large masses one to several square feet in area. These masses usually break up readily on coming in contact with rough water or with some hard object (such as a boat), and much of the material sinks at once and comparatively small amounts, if any, succeed in reaching the lower half of the river. On examination this material is found to be made up largely of chaffy matter together with small mats of *Carchesium*

and of fungus, with occasional filaments of blue-green algae and a few sludge worms (*Tubificidae*) intermixed.

(b) Other floating masses, greenish, very dark, or even black in color, and in size varying from a square inch to nearly a square foot, are somewhat tough, and do not disintegrate readily, nor break and sink after contact with some hard object. On examination these masses are found to consist almost wholly of blue-green algae, usually *Oscillatoria*, in the living condition. Sometimes a few sludge worms will be present also. These masses of blue-green algae will float for miles and are often abundant, especially in late summer, in the current of the lower river as well as in the middle and parts of the upper sections.

(8) The dark gray, sludgelike floating material seems to originate from the bottom, from which these masses are lifted by gases which accumulate within or beneath this lighter surface portion of the bottom sediments. Large bubbles of gas usually break at the water surface when this material is seen to rise from the bottom. This has been observed many times, especially in the La Salle section.

(9) The blue-green alga constituting much of the second class of floating material is known to grow in mats on the bottom, 1 to 5 feet under the water surface if the water is clear enough to admit sunlight. It also grows in feltlike layers covering stones or mud in the shallow water along stream margins, and in short tufts attached to sticks, stones, or other support. These algae have no roots or similar structures to hold the plants to the surface on which they grow. Their attachment is very slight, and from time to time mats of the growth will become loosened, peel off, and float downstream.

BIOLOGICAL REACTION

(References: Tables 3, 4, 11, 12, 15, 18, 25, and 30)

(10) Biological reaction to the rapid turbulent stream of heavily polluted water in the Joliet section is seen in the great prevalence, and the very large quantities, of such typical sewage organisms as are able to anchor themselves in the swift current that characterizes this section of the stream.

(11) Conversely, free-swimming and nonattached organisms are relatively few in this section of the stream, except certain diatoms, known as Lake Michigan species, which are continuously flushed through the canal, and certain unicellular green algae. Moreover, an important constituent of the plankton is the small fragments of ciliate colonies and fungi that have been broken from the anchored parent stalks and larger colonies by the turbulent waters.

(12) Practically no bottom sediments are deposited in this turbulent section, except in an occasional eddy near the shore, or in a

sheltered pocket. Such sediments as are present are black, with vile odor, but are usually granular, the finer suspended matter being carried away by the strong currents.

(13) Physical conditions favoring biological development in the upper river are: (a) Abundant organic content in the form of comparatively recent sewage; (b) thorough and continuous mixture, especially in the Joliet region. This latter factor will operate to determine the kinds of organisms that will develop, rather than the quantity. Absence of either the sewage or the turbulence would radically change the environment, and similar change in the kinds of prevalent organisms would result.

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TABLE NO. 3.—Average total plankton, each month, each station, and seasonal averages

Month	Des Moines River (292)	298	Kanawha River (272)	303	La Salle (257)	106	119	108	122	Green River (231)	100	Sam Houston River (99)	25
January	381	421	86	456	481	—	283	280	319	418	—	—	543
February	401	336	436	401	602	—	430	273	319	791	—	—	713
March	770	453	627	1,100	656	481	804	458	713	828	—	—	1,377
April	858	563	676	1,222	436	653	456	458	778	828	—	—	1,377
May	1,453	1,138	811	1,061	904	922	1,584	1,368	1,053	828	—	—	2,063
June	497	1,074	613	861	1,062	1,238	1,119	1,238	1,723	900	—	—	1,071
July	635	1,001	58	492	1,062	1,238	1,238	1,238	1,723	900	—	—	1,071
August	300	753	302	327	1,062	1,238	1,238	1,238	1,723	900	—	—	1,071
September	—	—	—	—	1,175	1,414	1,111	911	864	1,238	—	—	1,071
October	—	—	—	—	1,175	1,414	1,111	911	864	1,238	—	—	1,071
November	—	—	—	—	1,175	1,414	1,111	911	864	1,238	—	—	1,071
December	—	—	—	—	1,175	1,414	1,111	911	864	1,238	—	—	1,071
Spring average	1,010	1,448	673	1,000	600	—	840	787	1,123	790	—	—	882
Summer average	484	2,843	519	1,325	735	1,187	1,308	1,785	2,066	1,469	—	—	1,123
Autumn average	794	1,351	270	1,325	602	—	—	807	854	1,260	—	—	1,123
Winter average	446	215	448	1,536	747	—	330	303	285	873	—	—	1,123
Seasonal average 11 months	687	1,501	637	819	747	—	500	504	1,131	900	—	—	1,071

¹ Average of the given calendar month for 2 seasons, 1921 and 1922.

² October and November only.

³ 6 months only.

⁴ 6 months only.

TABLE NO. 4.—Pollutional organisms, each station, each month, expressed as per cent¹ of the total index organism content

Month	282	286	288	295	La Salle (227)	186	179	180	Havens (132)	Spokane River (121)	100	Sanjo River (90)	28	All stations *
January	63	50	53	73	77	67	69	63	63	69	69	69	0	60
February	41	43	73	70	79	64	59	53	53	59	59	59	0	64
March	57	54	71	76	86	75	58	53	53	53	53	53	0	64
April	67	54	71	76	86	75	58	53	53	53	53	53	0	67
May	58	54	71	76	86	75	58	53	53	53	53	53	0	55
June	51	51	71	76	86	75	58	53	53	53	53	53	0	55
July	51	51	71	76	86	75	58	53	53	53	53	53	0	55
August	51	51	71	76	86	75	58	53	53	53	53	53	0	55
September	63	50	53	73	77	67	69	63	63	69	69	69	0	55
October	58	54	71	76	86	75	58	53	53	53	53	53	0	55
November	47	40	40	40	41	43	41	41	41	41	41	41	0	55
December	40	44	40	40	41	43	41	41	41	41	41	41	0	55
All months *	50	54	49	60	60	53	53	53	53	53	53	53	0	55

¹ For quantity of index organisms see Table 23, column 7.² Conditions stations 186, 100, and Sanjo River.³ Where collections were taken during the same calendar month in the 2 years (1921 and 1922) the results are averaged.⁴ Omitting September.

(14) The middle and lower reaches of the river show, in a measure, the great biological action that logically follows the initial thorough mixing and the heavy seeding with suitable organisms. But conditions appear to be less suitable now than they formerly were, because the requisite time and area for adequate biological action have been greatly reduced since 1910 by levees which debar the river from its former back-water areas and compel it to flow, with increased speed, to its mouth.

(15) The biological reaction of the stream as a whole seems somewhat inadequate as to the plankton, in that these minute organisms appear to be less numerous than is consistent with the very large amount of sewage introduced into the upper river. As to the larger organisms, especially those in the bottom sediments, the reaction, as indicated by the relative abundance of these organisms present, seems inadequate except at certain points.

(16) Specific illustration of the adequate reaction of the smaller organisms is seen in the Joliet region, where the great abundance of stalked ciliates and sewage fungi find the two vital conditions of their optimum environment; that is, (a) heavy pollution and (b) rapid movement of water. (See Tables 15 and 18.) Water lacking heavy pollution, though in rapid motion, will not support these organisms, and likewise if rapid movement and turbulence be absent, the water, though heavily polluted, will not furnish a suitable environment for these particular organisms. Adequate biological reaction of the larger organisms is seen at the head of Peoria Lake. Here the sudden decrease in speed of current causes (a) a heavy deposit of suspended matter which is still (b) sufficiently rich in organic material¹ to support the very large numbers of tubificid worms present. Deposits farther downstream similarly extensive but apparently not rich enough in organic matter, yield comparatively few of these worms. (See Tables 30, 35, and 46.)

(17) The Des Plaines River at Sixteenth Street, Lockport (before the drainage canal is emptied into it) is characterized by an exceedingly heavy growth of filamentous green algae, together with a considerable quantity of other submerged green plants. Only during late winter and early spring were these plants scarce. Great masses of algae, chiefly *Cladophora*, obscured the bottom stones and trailed in the current. This condition was largely prevalent during September to December, inclusive, and May to August, inclusive. Moderate amounts were present during January to April, inclusive. (See Table 12.)

(18) The drainage canal at Sixteenth Street, Lockport, showed only occasional traces of any filamentous green algae. Microscopic

¹ See observations, p. 161, as to the strongly organic material produced by these worms.

chlorophyll-bearing organisms, chiefly diatoms known to be common in Lake Michigan, were fairly abundant. The mingled waters of the Des Plaines River and of the canal are thus seeded with an assortment of minute green algae from the former stream, a half dozen or more varieties of diatoms from the lakes, and certain organisms, chiefly ciliates, obviously due to the sewage component of the drainage canal. Table 54 (station 292, column 2) and Table 10.

(19) Filamentous green algae and similar large submerged plants are comparatively scarce in the upper Illinois. Occasional small backwater areas show a moderate growth of such plants, but even in Peoria Lake only a light growth of submerged aquatics is found. At no point in the Illinois is there an algae growth approaching the great abundance found in the Des Plaines River at Sixteenth Street, Lockport.

TABLE No. 5.—Station averages for entire sampling period on an 11 months' basis

Stations	Period of collection (months)	Plankton catch—cubic standard units in 1 c. c. of water											
		Total catch				Total organisms				Total organisms			
		Organisms			Asterophorus no.	Oxygen producers		Oxygen consumers		Index or- ganisms		Indifferent and of un- known value	
		Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner		
290.....	11	870	117	987	16,900	588	11	106	12	107	105	674	
Des Plaines.....	11	1,192	318	1,510	22,200	1,181	126	184	2	102	623	777	
291.....	11	506	145	651	14,300	405	21	144	17	124	106	801	
292.....	11	478	159	637	16,620	470	21	125	7	152	166	262	
Kankakee.....	11	325	72	397	26,640	320	30	65	3	35	64	315	
293.....	11	870	312	1,182	28,530	549	25	207	20	276	145	440	
297.....	11	511	227	738	24,280	504	26	260	5	213	137	288	
179.....	11	505	204	709	26,640	500	56	118	5	123	227	451	
166.....	11	676	230	906	25,900	671	131	127	5	99	330	697	
133.....	11	600	265	1,161	31,900	577	140	139	6	127	324	676	
Spoon River.....	11	904	56	960	179,670	667	63	81	7	71	151	585	
25.....	11	901	176	1,076	93,170	664	56	118	7	71	220	706	

PLANKTON CONTENT

(References: Tables 4, 6; fig. 19)

(20) Plankton examinations indicate that, in the section of river from La Salle to Chillicothe (station 179) where apparent physical conditions make a change for the better, an analogous change takes place in the predominant index organisms of the plankton (see Table 4, item all months), the pollutional organisms which have previously been in the majority in main-stream stations giving place gradually to the cleaner-water forms which now gain the ascendancy. All plankton collections taken during a period of 14 months, summarized

by seasons in Table 6 (see column "Per cent pollutional") show that the highest percentage of pollutional organisms was found each season at station 263, except in summer, 1922, when station 286 showed a slightly higher percentage. (Reference is made to main stream stations only.) Reducing the situation to its simplest terms (see averages for 11 months' collecting period, column 25) we find, for main-stream stations, that the peak production of pollutional organisms occurred at station 263, and that these organisms dropped below the 50 per cent mark some place below La Salle, and remained in the minority thereafter in all the lower river. (See fig. 19.)

(21) In the drainage canal plankton, pollutional organisms from the sewage, and clean-water organisms from Lake Michigan were about equally abundant, each constituting about 50 per cent of the index organisms. (See Table 6, station 292, in columns 9, 13, 17, 21, and 25.)

SEASONAL REACTION OF THE PLANKTON

(References: Tables 3, 5, 8, 50, 51, and 54)

(22) For the Illinois River stations the percentage ⁴ of pollutional organisms is highest in winter (66 per cent), though the actual volume of plankton (Table 3) is lower than in summer, during which season pollutional forms average 37 per cent of the index organisms. The heaviest yield of total plankton in summer at Illinois River stations is at Havana (station 122) and in winter the point of heaviest yield is farther south, at station 25, near the mouth of the river. (Tables 50 and 51.)

(23) In both summer and winter a definite increase in per cent of pollutional organisms is found at Havana (station 122) as compared with the nearest upstream station (station 166, just above the city of Peoria). (See Tables 50 and 51, column 5.) The same tendency is noted if the data be arranged by seasons, as in Table 6 (see columns 5, 9, 13, 17, and 21), or if data be averaged on the basis of 11 months. (See last column, Table 6.) This consistent increase in pollutional forms is probably due to the sewage of Peoria and Pekin, about 25 miles or more upstream from Havana.

⁴ Derived from Tables 50 and 51, omitting tributary stations Des Plaines, Kankakee, and Spoon.

TABLE No. 6.—Summary of plankton averages, all seasons, all stations

Sampling stations	Summer 1921				Autumn 1921			
	Total organisms		Index organisms		Total organisms		Index organisms	
	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent poli- tional	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent poli- tional
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Des Plaines River.....	700	71	214	84	1,281	88	798	10
Kankakee River.....	1,081	88	613	30	1,081	88	613	30
La Salle.....	270	86	800	49	270	86	800	49
Mossville.....	1,000	81	1,000	81	1,000	81	1,000	81
179.....	1,443	96	783	34	473	86	361	37
180.....	1,000	79	1,130	81	844	86	361	37
181 (Havana).....	1,700	73	684	46	841	91	482	31
182.....	1,134	90	144	16	840	90	341	31
183.....	1,013	73	600	46	1,307	97	80	14
184.....	1,100	90	1,143	48	1,000	89	360	30
185.....	1,107	90	737	41	1,007	87	617	34
Sampling stations	Winter 1921-22				Spring 1922			
	Total organisms		Index organisms		Total organisms		Index organisms	
	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent poli- tional	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent poli- tional
	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Des Plaines River.....	400	80	160	81	1,010	91	800	88
186.....	315	87	70	48	1,400	89	487	30
187.....	483	78	100	54	813	87	337	64
Kankakee River.....	600	90	120	40	700	81	300	71
188.....	300	90	40	31	673	79	100	10
189 (La Salle).....	800	80	300	84	1,001	87	300	80
190.....	667	80	300	80	600	75	214	30
191.....	800	73	100	70	670	81	160	30
Mossville.....	800	73	100	70	840	81	320	37
192.....	315	80	60	30	797	83	370	30
193 (Havana).....	300	79	47	47	1,184	83	300	13
194.....	873	90	40	16	800	84	100	0
195.....	800	90	80	8	1,005	90	100	3

TABLE NO. 6.—Summary of plankton averages, all seasons, all stations—Continued

Sampling stations	Summer 1922				Averages, on 11 months basis			
	Total organisms		Index organisms		Total organisms		Index organisms	
	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent pollu- tional	Stand- ard units per c. c.	Per cent oxygen pro- ducers	Stand- ard units per c. c.	Per cent pollu- tional
	(16)	(17)	(20)	(21)	(22)	(23)	(24)	(25)
200	804	79	100	45	687	38	313	90
Des Plaines River	2,543	83	1,895	11	1,851	87	734	14
201	836	73	316	84	673	78	312	68
202	519	70	280	67	617	77	285	60
Kankakee River	300	66	146	6	455	30	90	28
203	533	77	284	61	623	65	421	66
207 (La Salle)	679	63	383	43	730	73	380	60
195	1,100	81	465	60				
175	1,261	87	648	34	790	85	549	55
Monroville								
196	1,776	86	1,078	19	984	86	437	20
133 (Havana)	2,441	90	1,514	21	1,181	88	461	20
Spout River	1,547	90	631	5	864	90	164	5
197								
Sananton River								
20	1,138	82	413	10	972	86	237	22

(24) The plankton of the Des Plaines was characterized by the heavy predominance of minute chlorophyll-bearing organisms during the months of October, and March to August, inclusive. Slight predominance obtained in November to February, inclusive. (See Table 53, column 5; Table 5, column 7; Table 54, columns 2, 3, and 4. See Fig. 35.)

(25) At all stations the net results of plankton collection show a large volumetric predominance of such organisms as possess chlorophyll and therefore produce oxygen. This predominance of oxygen producers obtains in the relatively light winter plankton and also in the heavy yields of the warmer seasons as well. (Table 8.)

TABLE NO. 7.—Per cent of plant plankton, each station, each month, with seasonal and 11 months' averages

Month	202	Das Palas River	200	200	200	Kankar Jee River	200	La Salle (207)	100	170	Man- villu	100	122	Spom River	100	Samp- son River	25
1921																	
June								70					50	97	43	93	10
July								75					74	82	49	87	40
August								75					72	81	45	81	40
September								65					66	66	45	81	40
October								61					58	66	45	81	40
November								60					58	66	45	81	40
December								60					58	66	45	81	40
1922																	
January								81					83	91			
February								85					85	91			
March								85					85	91			
April								85					85	91			
May								85					85	91			
June								85					85	91			
July								85					85	91			
August								85					85	91			
Average, 1921:								77					66	90			
1922:								77					66	90			
11 months:								77					66	90			

(26) This latter finding is in general agreement with data obtained by Dr. C. A. Kofoed,⁶ who, in an extended study of the Illinois River plankton in 1894-1899, found that synthetic, chlorophyll-bearing organisms outnumbered the analytic forms 18 to 1. The two sets of data are difficult to compare, however, the earlier record being on the basis of numbers of organisms, while the data herein presented are on the basis of volume, all organisms, large and small, being stated in terms of cubic standard units.⁷ The essential and significant fact, i. e., the heavy preponderance of synthetic, oxygen-producing organisms, is emphasized in both sets of data.

THE BOTTOM SEDIMENTS

(Reference: Bottom-sediment tables in summary by stations section)

(26) The biological content and physical characteristics of bottom sediments appear to be in general agreement with the sanitary status of the overlying water as shown by the proportion of pollutional organisms in the plankton of this water.

(a) In the turbulent Joliet section the swift current prevents deposit of sediments (except in an occasional eddy) but the stones on bottom and along margins show a heavy growth of *Carchesium*, a minute colonial animal which is typical of polluted environment and a form that can not live in clean water. Such sediments as were obtainable in this section had a strong repulsive odor and contained an average of 1,700 tubificid worms (so-called "sludge worms," a well-known evidence of pollution) in a liter of mud, which meantime yielded none at all of such insect larvæ and other organisms as are common in the bottom mud of waters known to be fairly clean. (Tables 15 and 18.)

(b) At Chillicothe (station 179) though the water is nearly clear, looks clean, and is without odor, yet the plankton content indicates pollution and the bottom sediments confirm it. The sediments here are sticky and full of gas, have a strong unpleasant odor and contain very large numbers of sludge worms, a liter of mud averaging 2,250 of these pollutional organisms. In addition, however, organisms of widely varying requirements as to sanitary status of water—the larvæ of *Chironomus*—were not uncommon, averaging 9 per liter of mud. Meantime definitely clean-environment organisms began to appear, averaging one per liter of mud. (Table 30.)

(c) At Havana (station 122) the clear, clean-looking water has no odor. The plankton indicates increase in pollution (see p. 48, par. 23), obviously due to sewage of Peoria and Pekin. The bottom sediments have but slight odor, and insect larvæ of the cleaner-water forms (May fly, dragon fly, caddis fly, etc.) average 5 per liter of mud,

⁶ Bulletin Illinois State Lab. Natural History, Vol. VIII, Article I, p. 17.

⁷ Reducible to parts per million by volume by dividing by 125.

the tolerant or indifferent *Chironomus* larvae average 9 per liter, and the pollutional sludge worms have decreased to 41 per liter. (Table 35.)

(d) At station 25 (below Kampsville) the clear, clean-looking odorless water shows only occasional pollutional organisms in the plankton. The bottom mud is granular, is practically without odor, contains only a few sludge worms, and shows many insect larvae and other forms of life that are commonly found in streams that are known to be relatively free from gross pollution by sewage. These clean-environment organisms here average 52 per liter of mud, while the pollutional sludge-worms average only 12, a definite and significant change from the averages of 0 and 1,700, respectively, for these two classes of organisms in the Joliet section of river. (Table 46.)

CHAPTER VI

THE UPPER RIVER, SUMMARY BY STATIONS

Herewith will be given a résumé of the prevailing conditions at each sampling station. These conditions will include a statement of the physical characteristics exhibited by the stream, and a summary of the biological findings as shown by an examination of plankton samples taken weekly and of bottom sediment or other samples taken monthly as a rule, or less often.

Inasmuch as the sampling covered a period of about one year, these summaries by stations will be divided into periods corresponding in general to the season: autumn, winter, spring, and summer, and including the months September to November, December to February, March to May, and June to August, respectively and inclusive. It is thought that this arrangement will give due prominence to such seasonal fluctuations as are of sufficient amplitude to warrant consideration and at the same time will avoid the tedious and unnecessary elaboration of data that would result from separate summarizing of each month's results.

In addition to the classification of organisms in their respective families or groups, as in such tables as 10, 14, 16, 20, etc., and the weekly data in Table 54, it has seemed necessary to indicate, in the text, the relative abundance of such subgroups as make up the main family or group mentioned. Thus, in Table 14, for example, we note that diatoms, green algae, and flagellates (or mastigophora) make up the bulk of the plankton in October, but this table gives no data as to whether the diatoms, for instance, are made up of one kind or of several. This phase of the data is therefore taken up in the text (see page 68), where it is definitely stated that the diatoms, green algae, etc., in the October plankton were made up of certain subgroups which are named, and the approximate relative abundance of each is stated.

The above plan, in general, has been followed throughout. Though necessarily tiresome at times, it seems to be the only feasible way of presenting, relative to the *kinds* of organisms, the amount of information required for a proper appraisal of a given situation biologically considered. A similar plan, but more elaborate, was followed by Doctor Kofoid in his discussion¹ of the plankton organisms of the Illinois River in 1908.

¹ Bull. Illinois State Lab. Nat. Hist., Vol. VIII, art. 1, 1908.

The tabular statement of the result of each month's inspection by the visiting biologist and the data obtained from examination of bottom sediments and other samples, will be found in Tables 11, 12, 15, 18, 25, 30, 35, 38, 43, and 46, and will form the basis of the seasonal résumé here given. Also, the data as to weekly plankton samples, together with monthly summaries of the same, are given for all months in Table 54, and in numerous tables to be found in the summary by stations section. These data in turn constitute the basis of the résumé here given relative to plankton life.

Altogether, an effort is made, in the successive portions of this résumé, to obtain from the properly accredited biological agencies at work in each representative portion of the river, such testimony as may be available relative to the sanitary status of the water and the apparent prospects for its ultimate and speedy purification.

STATION 292: CHICAGO DRAINAGE CANAL AT SIXTEENTH STREET,
LOCKPORT

The canal at this point, thirty-odd miles below Chicago, is a stream 160 feet wide and about 23 feet deep, flowing slowly between a perpendicular wall of concrete on the east and a levee or bank on the west formed of earth and faced, next to the stream, with a sloping riprap of large stones which extends also some distance out into the canal at the bottom.

In several respects the conditions at this point are not those of a natural, polluted stream, by reason of the following facts:

(1) The volume of water is not subject to any great seasonal change. Instead of the fluctuating drainage from a watershed, augmented by heavy rains or spring thaws and later diminished by prolonged drouth, the water of the canal is a practically continuous supply pumped from Lake Michigan, and is consequently lacking in the marked seasonal fluctuations of volume that are so characteristic of a natural stream.

(2) Practical constancy of rate of supply is chiefly responsible for similar constancy in the general rate of water movement so far as seasons are concerned. There are no fast-moving spring floods, for instance, to scour the channel.

(3) Similarly, there are no periods of high turbidity comparable with turbidities in a natural watercourse.

(4) There are no tributaries whose swollen waters may, on occasion, materially affect the normal volume, or the usual quality of the waters of the main stream, as in a natural watercourse.

(5) There are no marked inequalities in depth, width, or slope of the canal. The usual succession of pools, riffles, and shallows found in an ordinary stream, with swift current alternating with slow movement, and with continuous turnover of water, effecting exposure to a

relatively very large air surface, is absent from the canal. Slope of the canal is less than 2 inches per mile.

(6) The degree of sewage pollution is about the same throughout the year, due to the practically constant supply from the Chicago sewers. In the average polluted stream the spring thaw releases to the water a considerable amount of organic refuse that had been frozen up during the winter in drains and shallow tributaries and temporarily withheld from the stream. The high spring floods flush out low-lying areas, stream margins, drains, and sewers. It is a sort of annual house-cleaning event. This does not take place in the drainage canal.

(7) The canal possesses a final peculiarity in that the flow of water, though practically constant as to season, nevertheless fluctuates considerably during the 24 hours. This is due to the fact that the power house, located at the lower end of the canal (and about 1 mile below station 292), uses the water to generate electric power which is used to furnish light in Chicago streets. The power house is therefore active at night, and the water, drawn off for this purpose, flows through the canal faster than it does in daytime. Further, during the day the water accumulates to some extent in the canal, thus reaching a higher level than it does at night. This causes a sort of local "high tide" by day and "low tide" by night along the canal, and the great volume of water thus irregularly discharged into the Des Plaines River below the power house causes a somewhat similar succession of small daily tides for several miles downstream.

It will thus be apparent that the drainage canal differs, in several important respects, from the average sewage-polluted stream. In fact, the canal is merely a relatively straight deep trench with uniform slope (less than 2 inches per mile), and steep or perpendicular sides, through whose length of 38 miles water chiefly² from Lake Michigan is caused to flow slowly in order to dilute and remove the sewage and organic wastes of a large city. It is essentially the transfer of lake water, the initial heavy pollution by Chicago sewage being about the only outstanding event to break the monotony of its journey to Lockport. Here the more eventful portion of its history begins in its thorough mixing by the passage through the turbines of the power house, involving a descent of 34 feet, and continued, after combining with the Des Plaines, by the turbulent journey over the bed of that stream whose initial 8-mile section has an additional fall of about 52 feet. It is thereafter subject to the irregularities of channel, seasonal change in volume, dilution by tributaries, drainage from adjacent lowlands, frequent turbidity—in short, all the factors that affect the average watercourse, for the canal has now become a river.

² A portion of the water is furnished by North Fork of Chicago River.

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October and November, 1921.—As already indicated, there is little fluctuation of conditions at this station. During this autumn period the slowly moving water was nearly clear, but with slight grayish aspect due to rather large numbers of minute flecks and masses, chiefly *Epistylis* and *Carchesium*, floating and suspended in the water. Moderate numbers of small dead fish (obviously from the lake) were floating, together with small amounts of debris and traces of grease. A slight odor of sewage was noticeable, but this all but disappeared as the weather became colder. Marginal stones showed small amounts of a blue-green alga, *Oscillatoria*, but this, together with most of the visible floating bits of *Carchesium*, became greatly reduced in amount as winter approached.

Plankton collections likewise showed by decreasing volume the effects of increasing cold, the total catch averaging 819 units³ in October and 770 in November. A certain portion (one-third to one-half) of the total plankton consisted of such organisms as are known to react definitely for or against sewage pollution. Of these active pollution-index organisms, the October average of 363⁴ units showed 211 indicating pollution and 152 indicating relatively clean water. Similarly, the November index of 265 units showed 126 for pollution and 139 for cleaner water.

TABLE NO. 9.—Summary of plankton findings for all months

AVERAGES AT STATION 203

Date	Flankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms				Total organisms			
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown action	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner		
1921												
October.....	387	802	819	13,000	337	19	203	0	211	122	430	
November.....	344	706	790	21,000	337	4	300	7	130	139	508	
December.....	606	78	643	27,000	333	11	68	14	91	126	415	
1922												
January.....	300	73	363	11,000	300	5	67	19	98	30	300	
February.....	303	78	381	11,100	304	5	68	20	96	34	300	
March.....	737	84	770	17,400	710	7	30	27	130	129	590	
April.....	717	80	808	20,100	705	21	40	12	130	62	615	
May.....	1,817	180	1,658	6,400	1,314	12	136	5	140	106	1,100	
June.....	303	140	408	20,000	303	0	141	8	97	90	300	
July.....	303	68	405	14,300	349	13	50	13	60	170	301	
August.....	367	115	300	13,400	380	10	90	17	109	61	100	
Averages for 11 months.....	670	117	687	16,800	538	11	100	12	107	105	474	

³ All plankton values are expressed as cubic standard units, all organisms, large or small, being reduced to terms of this unit. It is analogous to the "square inch" of board measure, which, however, is also 1 inch thick, hence is 1 cubic inch.

⁴ See Table 6, columns 10 and 11.

The fact that pollutional organisms are not greatly predominant may seem at first thought a most inconsistent matter in consideration of the known heavy pollution of the canal water. Two facts, however, are sufficient to reconcile the apparently divergent items: (1) A large proportion of relatively pure water from the lake dilutes⁶ the sewage and flushes it through the canal. The cleaner-water plankton forms appearing in the samples are chiefly Lake Michigan diatoms and other minute algae of similar habitat. (2) The recent origin of the sewage does not permit sufficient time for the development of the maximum crop of sewage organisms by the time (two days or less) station 292 has been reached. Hence the plankton content shows the combination of relatively few organisms in recent sewage mixed with the moderate numbers of cleaner organisms incident to the larger proportion of Lake Michigan water.

A tabular statement of the various groups of plankton organisms is given in Table 10. It will be noted that an average of the nine autumn collections shows minute green algae to be the dominant group, forming 48 per cent of the average total plankton.

TABLE NO. 10.—Classification of plankton organisms
STATION 292, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c.c. of water										
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Sperm., etc.	Total
1921											
October.....	108	63	379	.....	.....	10	192	3	40	14	.....
November.....	155	18	286	7	.....	4	134	.....	32	44	.....
December.....	187	66	347	14	8	11	50	.....	.....	7	.....
1922											
January.....	55	49	108	18	3	5	50	1	.....	6	.....
February.....	58	54	305	36	.....	10	46	1	.....	14	.....
March.....	481	59	188	37	8	7	16	3	.....	.....	.....
April.....	613	30	274	13	.....	21	36	3	.....	16	.....
May.....	366	48	223	3	.....	13	107	10	.....	6	.....
June.....	80	20	223	3	1	.....	86	7	34	30	.....
July.....	191	65	206	13	.....	31	17	.....	.....	30	.....
August.....	15	43	173	17	3	10	67	0	.....	15	.....
Averages:											
Autumn.....	133	37	379	4	.....	11	154	3	60	31	791
Winter.....	99	47	264	16	3	9	33	1	.....	3	630
Spring.....	684	43	230	14	3	13	70	3	.....	5	1,005
Summer.....	95	45	335	12	1	14	58	6	3	20	434

December, 1921, January and February, 1922.—The advent of winter brought no visible changes to the environment at station 292 except such as were obviously due to lowered temperature. There were traces of ice along margins. No odor could be detected. No suspended masses, large or minute, could be detected even after

⁶ About 7 volumes of lake water to 1 volume of sewage. See Report of the Engineering Board of Review of the Sanitary District of Chicago on the Lake Lowering Controversy and a Program of Remedial Measures. Part II, p. 37. Published January, 1920.

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close inspection, although the water was slightly grayish in color. There was no surface floatage, except traces of oily material. No alga growth of any kind appeared in water or on stones along margin. The nearly clear, odorless stream had the superficial appearance of a clean water.

Examination of the bottom mud told quite another story. The mud was black, with strong and very offensive odor. No organisms were found in this mud except a considerable mass of *Leptomitris*, a fungus known to be characteristic of heavily polluted environment. This growth was probably scraped from the bottom stones by the mud scoop. (Table 11.)

The plankton catch averaged 642, 381, and 435 units respectively, in the 3 months, then low values being due in all probability to the cold weather. (Table 9.)

TABLE NO. 11.—Bottom sediments and conditions of water surface and stream margins

STATION 381			
Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921 Sept. 2	No bottom sample obtained until Jan. 30, 1922.	(1) Slow current; moderate odor of sewage; (2) few dead minnows and small amount debris floating.	(1) Rock and concrete margin; no shallow water; (2) small amounts blue-green alga on marginal stones.
27		(1) Moderately clean; (2) <i>Sphaerotilus</i> and <i>Epithemia</i> floating in small amounts; also dead minnows, 27 of these passing a given point in 1 minute.	(2) Coating of blue-green alga (<i>Oedogonia</i>) on stones along margin.
Nov. 20		(1) Color grayish; no odor; (2) very small amount <i>Carchesium</i> ; oily scum and floating debris in small amounts.	(2) No plants.
1922 Jan. 30	(1) Rocky bottom; small amount mud secured; this was black, soft, and had very offensive odor of putrefaction; (2) <i>Leptomitris</i> abundant.	(1) Nearly clean, with grayish color; no odor; (2) small amount oily matter floating.	(1) Traces of ice; no odor; (2) same.
Apr. 7	(1) Black, soft, with offensive turry odor; (2) few tubifex worms; small amount <i>Carchesium</i> and <i>Sphaerotilus</i> .	(1) Nearly clean; no special odor; (2) moderate amounts of <i>Leptomitris</i> and <i>Sphaerotilus</i> ; also shreds of paper, floating.	(2) No plants.
May 13	(1) Black, soft-granular, with moderate odor of sewage; (2) <i>Carchesium</i> in moderate amount.	(1) Grayish color; slight odor noticeable; (2) small dead fish floating in large numbers, and large total amount of <i>Carchesium</i> floating in small masses.	(1) Perceptible odor; (2) no plants.
June 28	(1) Black, soft, with moderate odor of sewage; (2) (catch lost by breakage).	(1) Nearly clear; slight odor; (2) moderate amount of <i>Carchesium</i> in small masses; few small dead fish, bits of fungus, and oily scum constitute other floatage.	(1) Perceptible odor; (2) no plants.
July 31	No sample obtained on account of rocks.	(1) Water high; very slight current; surface nearly clean; slight odor; (2) a few dead minnows and small amounts of <i>Carchesium</i> floating.	(1) Slight odor; (2) no plants.
Aug. 20	No sample obtained on account of obstructing rocks.	(1) Nearly clear; looks clean, slight odor; (2) one dead minnow floating, and one living one, but almost dead.	(1) Moderate odor of sewage; (2) traces of blue-green alga on stones along margin.

The heavier autumn collections averaged 54 per cent (of the active pollution-index organisms), indicating heavy pollution, and 46 per cent, indicating cleaner water. The winter collections just recorded show a very similar division, 52 per cent and 48 per cent, respectively, for the three months' collections. Thus the plankton content tends to corroborate the testimony of the bottom sediments relative to the actual heavy pollution of the water notwithstanding the lack of odor and the seemingly clean condition that would be apparent to the casual observer.

Minute green algae are again the predominating group of organisms, forming 54 per cent of the average total in winter catches, as shown in Table 10.

March, April, and May, 1922.—Water showed a slight grayish cast, but closer inspection revealed large numbers of small masses of flocculent matter floating at various depths. Size of these masses varied from that of a rice grain to about the dimensions of a large grape. A few masses of larger size were observed. These flocculent masses consisted chiefly of *Leptomitris* and *Sphaerotilus* in April, and in the following month *Carchesium* made up the bulk of this suspended material. There was very little surface floatage, except small dead fish, which were numerous. A slight odor of sewage was noticeable. No alga growth appeared in the water or on the stones at the margin.

Samples of bottom mud obtained in April were black, and had a foul, tarry odor. The mud contained a few tubificid worms, and small amounts of *Carchesium* and *Sphaerotilus*. Bottom samples obtained in May were black, with only moderate odor, and were slightly granular, as compared to the very soft, pasty mud that characterized former samples.

The plankton content showed great increase. The average for March, 770 units, was an increase of 77 per cent over the average for the preceding month. The April average of 806 units continued the general increase, while the average for May, 1,453 units, reached the highest value for the year at this station. The average total for the three spring months was an increase of 108 per cent over the average total for the three winter months.

The index organisms of the plankton showed a slight preponderance of the pollution forms during these spring months.

The plankton groups recorded in Table 10 show that diatoms are strongly predominant during these spring months, making up 62 per cent of the average total plankton. The increase of 108 per cent over the winter months is due chiefly to this increase in diatoms, which have risen from an average of 83 units (winter) to an average of 632 units in these spring samples. Meantime the average content of algae (both green and blue-green), and of ciliates has changed but little from the average winter values of these respective groups.

June, July, and August, 1923.—During these summer months there was perceptible odor of sewage. Water was nearly clear, except for small flocculent masses in suspension. These, chiefly *Carchesium*, were abundant in June, but relatively scarce in July and August. Surface floatage consisted mainly of oily scum and a few small dead fish. In August, one small living fish was seen by the writer. It was at the surface, trying to get air, and apparently in great distress. No algae could be found in the canal, and only very small amounts on the stones at the margin. This was the usual blue-green *Oscillatoria*.

Mud samples could not be obtained on account of violent contact of scoop with rocks on the bottom of canal, though repeated trials were made.

The plankton averages showed heavy decrease from the high values present during the spring. Index organisms averaged for the three months showed a slight predominance of the cleaner forms.

Summary.—The essential conditions as shown by a year's study of the situation at station 292 may be briefly summarized as follows: A relatively large volume of lake water mixed with the sewage and organic wastes of more than three million population has flowed about 30 miles in two or three days, through a deep, wide ditch of constant size and uniform slope. The volume is practically constant and the rate of flow uniform, except for minor day-and-night fluctuations. There are no tributaries. Turbidity is lacking. Seasonal fluctuations do not occur, except those due chiefly to temperature. On account of uniform cross section of the canal and the low gradient, there is relatively little exposure to air, and apparently only slight turnover of the large body of water. Thus the canal is an unnatural stream, in several respects.

Bottom sediments show the gross pollution incident to the suspended matter of the sewage constituent. Plankton organisms, in the half-and-half proportions indicating heavy pollution and cleaner water respectively, reflect (1) the imperfect development due to recent origin of sewage, and (2) the large admixture of pure water from Lake Michigan. Seasonal fluctuations of organisms are apparently such as are due to temperature, and to the yearly cycle. The heaviest growth is in the spring.

Kinds of organisms.—As already stated, the plankton organisms indicating pollution and those characteristic of cleaner water were in practically equal proportions throughout the year at station 292. The particular organisms making up these two groups in the collections taken were as follows: Organisms indicating sewage pollution were chiefly *Carchesium*, *Epistylis*, and *Vorticella*, usually in very small masses, or even single detached heads. These, with the ciliate *Colpidium*, were present in practically every collection taken. *Rotifer tardus* was present in several samples, these representing the entire

four seasons, and *Paramecia* was occasionally present, though the sewage was of too recent origin to expect them in large numbers. *Euglena viridis* was found in the spring and summer collections.

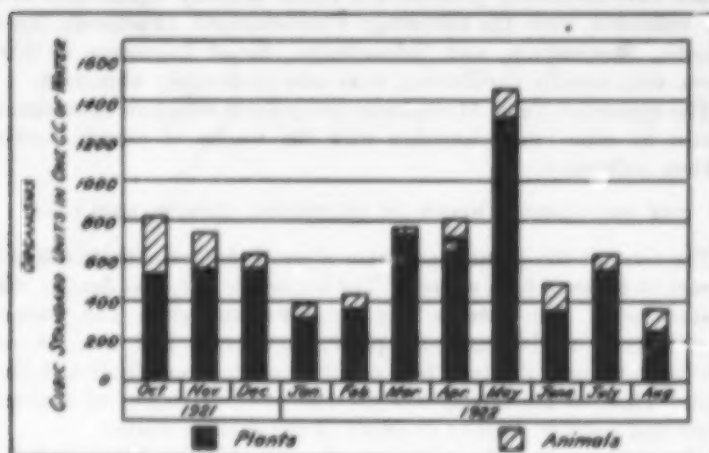


FIGURE 3.—Station 202. Monthly averages of weekly plankton catches expressed as plants and animals

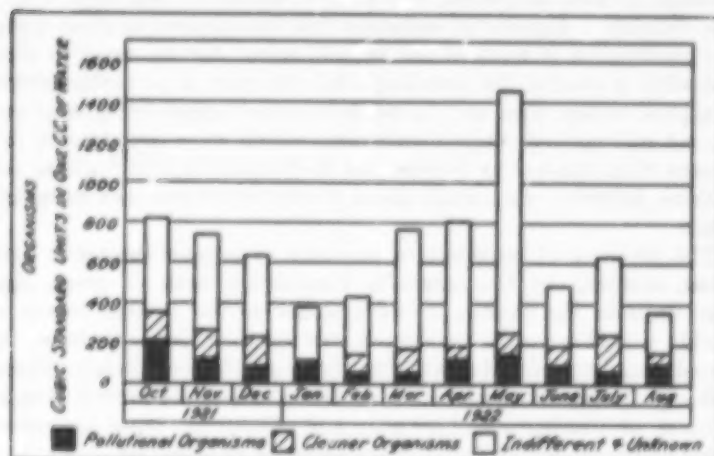


FIGURE 4.—Station 202. Monthly averages of weekly plankton catches expressed as pollutional, cleaner, and indifferent

The cleaner-water organisms were chiefly diatoms from Lake Michigan, *Tabellaria fenestrata* and *T. flocculosa*, the minute green alga, *Tetraspora*, *Botryococcus*, *Scenedesmus*, *Actinastrum*, *Pediastrum boryanum*, *Dictyosphaerium*, *Raphidium*, and *Pandorina*.

Various other diatoms were present, such as *Asterionella*, *Synedra*, *Melosira*, and *Navicula*, but the status of these toward sewage pollution is still in doubt. Likewise certain of the minute green algae which were commonly present, but whose sanitary significance is as yet unknown, were the following: *Pleurococcus*, *Crucigenia*, *Sphaerocystis*, *Staurastrum*, and *Selenastrum*. Small fragments of blue-green alga, usually *Oscillatoria*, were also moderately abundant.

The appended Table 11 indicates the general situation at station as shown by nine visits, together with the results of examination of bottom sediments.

THE DES PLAINES RIVER AT SIXTEENTH STREET, LOCKPORT

The river at this point is a stream of small size, essentially a brook, except at times of high water.⁶ The banks are low, and flanked with pasture land. The water is fully exposed to sunlight. The gradient is quite steep at this particular place, the water, 1 foot deep or less, flowing down over its stony bed, or slackened temporarily in a shallow pool. There is apparently the greatest possible degree of exposure to air and sunlight, and of overturn of the shallow water.

About 20 to 30 miles upstream the Des Plaines River is rather heavily polluted with sewage wastes from certain outlying portions of Chicago, notably Maywood, Des Plaines, Riverside, and other suburban districts. Apparently sufficient time has elapsed to effect material purification of most of the organic waste, for the water is clear and without odor at this sampling point and there is no visible growth of typical sewage flora and fauna such as the fungus *Sphaerotilus* and the colonial stalked ciliate *Carchesium*, which were abundant in this stream when studied by Forbes and Richardson in 1913,⁷ whose collections, however, were made about 2 miles above our own collecting point.

The presence of considerable amounts of organic matter is indicated, however, by the unusually luxuriant growth of green algae that trails in the shallow water and covers the bottom stones so thickly that these could be located only by their shape, or form, the actual stone surface and much of the bottom being completely hidden. This alga frequently showed, to a moderate extent, the growth of small colonies of *Carchesium*, *Epistylis*, and *Vorticella*, these organisms being unquestioned evidence of the presence of pollution.

September, October, and November, 1921.—Water was clear, turbulent and without odor. An amazing amount of green algae was pres-

⁶ The Des Plaines River is a stream of wide fluctuation, with no constant and reliable fountain supply. During some seasons its whole discharge would pass through a 6-inch pipe; at others its volume reaches 600,000 cubic feet per minute, when it rolls majestically along, flooding the whole valley. The Sanitary District of Chicago, and the Chicago Drainage Canal: A Review of 20 Years of Engineering Work. By Isham Randolph, p. 4.

⁷ Bull. Illinois State Lab. of Natural History, Vol. IX, Art. X, p. 302.

ent, even up to November 30, at which time the quantity was not perceptibly lessened, and the prevailing color was still that of a vigorous, vegetative green alga. *Cladophora* was by far the most predominant at all times. In September moderate quantities of *Spiregyra* and the pollutional green alga *Stigeoclonium* were present also. Small amounts of *Epistylis* were found among the alga masses, thus bearing further testimony to the presence of considerable amounts of organic matter in the water. This sanitary status was further indicated by the presence of some tubificid worms in the alga, the water being too swift for the deposit of sediments which provide the usual environment for these worms. Large numbers of chironomid larvæ and a few snails were apparently foraging in and on the alga. (Table 12.)

TABLE NO. 12.—Bottom conditions, water surface, and stream margins
DE LAINE RIVER AT SIXTEENTH STREET, LOCKPORT

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growth, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921 Sept. 2	Stony bottom; no mud; stream shallow; bottom conditions could usually be observed through the shallow water; alga often completely covering these bottom stones.	(1) Water low, clear, and current brisk; shallow riffles; stones emergent in places; no odor; (2) heavy growth of alga, some of which trailed on the water surface.	(1) Irregular, earth banks; water shallow; no shade along margins; (2) very heavy growth of <i>Cladophora</i> , <i>Stigeoclonium</i> , and <i>Spiregyra</i> trailing in currents and covering bottom slopes; a few tubificids among alga masses, and small tufts of <i>Epistylis</i> ; many small shells (<i>Pimephila</i>) on shore.
27	No mud; bottom alga (<i>Cladophora</i>) contained a few snails and many chironomid larvæ.	(1) Water clear, turbulent, and shallow; no odor; (2) trailing alga buoyed up by the brisk current. (See next column.)	(1) Irregular, low banks of earth; (2) <i>Cladophora glomerata</i> in very large amounts trailing in current and encrusting bottom; many <i>Chironomus</i> larvæ and a few snails among alga.
Nov. 30	No sediment; stones and alga only.	(1) Water high; surface turbulent, no odor; (2) Much alga near the surface. (See next column.)	(1) Water turbulent and eddies; (2) <i>Cladophora glomerata</i> , very abundant, as in September, looks green and vigorous, but much of the surface of alga filaments is covered with minute green scalelike growth of alga-like cells. (See fig. 24.)
1922 Jan. 30	No sample; bottom obscured by surface ice.	(1) Water high and clear; current rapid; most of surface sealed with heavy ice, only a narrow strip 2 to 6 feet wide in midchannel remaining open; (2) small amounts of ice floating in the narrow central channel.	(1) Margins sealed with ice; no odor; (2) moderate growth of <i>Cladophora</i> trailing from bottom stones; alga surface thickly studded with scalelike alga and with a few diatoms; 4-foot boom, apparently dead, in small ponds connected with margin of stream.
Apr. 7		(1) Water high and turbulent; no odor; (2) small amount <i>Cladophora</i> buoyed up on surface by rapid current.	(1) The usual margins covered by the high water; (2) <i>Cladophora glomerata</i> in small to moderate amounts attached to stones and well covered with the scalelike green organisms; a small amount of <i>Scenedesmus</i> found; brownish slime on stones composed chiefly of diatoms (<i>Eutima</i> and <i>Navicula</i>); a few small snails under the stones; many shells of <i>Pimephila</i> on shore above water line.

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TABLE No. 12.—Bottom conditions, water surface, and stream margins—Continued
DELAWARE RIVER AT SIXTEENTH STREET, LOCKPORT—Continued

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1922 May 12	No sample collected; only algae-covered stones present; no mud.	(1) Water somewhat high, turbulent, and without odor; (2) a tremendous growth of <i>Cladophora</i> (chiefly <i>C. crispata</i>) covering all the shallow expanse for nearly one-fourth mile above the bridge; this alga blanket was several acres in extent; minute scalelike organism (see fig. 34) abundant as usual on surface of alga filaments.	(1) Strewn with portions of alga blanket; (2) very large quantities of <i>Cladophora glomerata</i> in 3 to 8 foot masses trailing in current, but most of water surface was concealed by the great blanket of <i>C. crispata</i> ; snails (<i>Limnaea palustris</i> and <i>Planorbis</i>) very abundant in trailing alga masses; <i>Chironomus</i> eggs and capsules of leech found also; a few small fish were seen among alga masses, and 5 or 6 good-sized carp (1 foot long) were nosing in bottom of pool by the bridge.
June 23	No sample collected.	(1) Water about down to normal stage; turbulent, but no odor; (2) only small amounts of alga on surface of a few marginal puddles; the several-acre blanket of May 12 has disappeared.	(1) Water clear and turbulent; (2) large amount <i>Cladophora</i> covering bottom stones and trailing in the current; also <i>Stigeoclonium</i> in moderate amounts and a single specimen of <i>Monostroma</i> ; <i>Potamogeton</i> trailing in the current and nearly as plentiful as the alga; many snails (<i>Planorbis</i> and <i>Limnaea</i>) among alga.
July 31	No sample.	(1) Water low, turbulent, clear, and without odor; (2) alga trailing in surface, buoyed up by current.	(1) Water clear, low, looks clean; no odor; (2) very large amount <i>Cladophora glomerata</i> trailing in current; moderate amount <i>Stigeoclonium</i> , and grasslike <i>Potamogeton</i> abundant; innumerable snails (<i>Limnaea palustris</i> and many <i>Planorbis</i> also) in alga; leeches moderately abundant under stones.
Aug. 29	No sediment available.	(1) Turbulent and clear; no odor; (2) moderate amounts <i>Cladophora</i> in yellowish mats on surface near margin.	(1) Water clear; no odor; (2) yellowish mats of <i>Cladophora</i> along margins; very large amount <i>Cladophora glomerata</i> trailing in current and bearing a heavy growth of the green scale-like organisms, some diatoms, and <i>Leptothrix</i> ; snails (<i>Limnaea palustris</i>) very abundant, <i>Planorbis</i> less so, and leeches in moderate numbers; slender <i>Potamogeton</i> trailing in the current; several small frogs seen, but no fish.

In November a green coating made up chiefly of a pleurococcus-like growth, covered portions of the bottom stones. Also, much of the surface of the filaments of alga (*Cladophora*) was covered by a minute scalelike growth, green in color, which however was more than half as thick as its width, the average dimensions being in the ratio of 7, 4, and 2½, representing length, width, and thickness, respectively. An abundant growth of these minute organisms on a small filament of alga gave the latter a curiously chainlike appearance. (See fig. 34.)

Measurement of these scalelike alga covering a thread of filamentous alga as shown in the above photomicrograph shows that the actual surface provided by these organisms (counting the outer surface, the

ends, and the sides of each scale) is represented by 3,615 units of area, as compared to the 1,886 units of area provided by the original alga filament which is, in the photograph, covered by these scales. Thus the alga, becoming defunct near the end of the growing season, is used as a convenient attachment for these smaller, scalelike algæ which may cover the original alga thread to such an extent that the working surface of the latter is actually more than doubled. This being true, it logically follows that the decreasing oxygen-producing capacity of the once-active filamentous alga may be to some extent regained, or perhaps even increased by the minute encrusting alga which now finds lodgment on the alga thread.

Conditions similar to the above were found in the Potomac³ River, where, late in the autumn, the physiologically inactive eelgrass served as an attachment for inconceivable numbers of diatoms, and for minute green algæ as well, whose greater combined area and proportional activity in producing oxygen probably far surpassed that of the eelgrass, even when the latter was in its prime.

In addition to the chironomid larvæ and the few tubificid worms, there were considerable numbers of snails among the alga masses. There were *Planorbis* and *Limnea* genera. No mud samples were obtainable, all suspended matter being swept out by the swift current.

The autumn plankton.—Total plankton yield in October averaged 2,312 cubic standard units, with plants greatly in predominance. The majority of the index organisms were of the cleaner-water varieties. (See Table 13.)

TABLE No. 13.—Summary of plankton findings for all months
AVERAGES AT STATION DES PLAINES RIVER

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms				Total organisms			
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutifloral	Cleaner		
1921												
October.....	1,937	375	2,312	22,300	1,084	284	141	8	165	1,205	945	
November.....	238	52	290	18,900	228	18	32	0	66	72	249	
December.....	281	26	257	10,100	221	18	8	9	20	28	210	
1922												
January.....	102	17	119	7,400	102	6	11	0	12	19	96	
February.....	190	69	259	6,000	195	10	59	4	61	79	127	
March.....	558	72	631	49,600	558	35	28	0	42	53	537	
April.....	472	111	583	32,900	472	26	86	0	70	60	453	
May.....	2,569	556	3,125	15,100	2,569	276	280	0	180	1,056	1,891	
June.....	2,014	1,090	3,074	37,400	2,014	287	774	0	174	1,306	1,594	
July.....	2,439	562	3,001	25,100	2,439	285	277	0	162	1,709	1,009	
August.....	2,152	600	2,752	21,100	2,141	170	430	11	140	1,266	1,346	
Averages for 11 months.....	1,183	318	1,501	22,250	1,181	124	194	2	102	622	777	

³ Potomac Plankton Studies. Purdy. Hygienic Lab. Bulletin No. 104, p. 176. Also figs. 26 and 27.

With regard to oxygen production, the weekly average plankton for October showed a great preponderance of oxygen producers, as compared to those organisms which are animallike in their metabolism and are therefore oxygen consumers.

November total plankton showed a heavy drop, the average being only 390 units, with cleaner-water forms slightly in the lead. As to oxygen production, 91 per cent of the total of 390 units were producers, and 9 per cent were classified as consumers.

It is worthy of note that the visible biological and physical mechanism in the Des Plaines (that is, the unusual quantities of green algae in the clear, shallow water, with unhindered access of sunlight) which has to do with the production of excess oxygen, is further supported and extended even in any given minute quantity of the water. This is by the invisible mechanism of like nature and function as expressed by the very high percentage of chlorophyll-bearing oxygen-producing organisms in the plankton. See figure 35, also Table 14.

TABLE NO. 14.—Classification of plankton organisms
STATION DES PLAINES RIVER, MONTHLY AND SEASONAL AVERAGES

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	Total
1921											
October.....	156	10	1,768	3	6	234	42	31	53	10	.....
November.....	11	85	242	.....	.....	18	29	1	.....	4	.....
December.....	7	17	208	.....	.....	18	2	2	.....	4	.....
1922											
January.....	.....	12	90	.....	1	6	7	.....	2	.....	.....
February.....	10	70	115	4	.....	10	59	.....	.....	.....	.....
March.....	22	20	508	6	2	35	29	1	3	5	.....
April.....	30	42	400	.....	.....	26	86	.....	.....	.....	.....
May.....	529	107	1,004	.....	8	276	5	249	16	1	.....
June.....	499	.....	1,525	.....	9	287	123	424	216	2	.....
July.....	201	47	2,190	.....	1	285	15	137	117	8	.....
August.....	89	36	2,024	11	22	170	34	20	245	8	.....
Averages:											
Autumn.....	75	52	920	1	3	114	35	14	9	7	1,220
Winter.....	6	25	131	2	0	11	25	1	1	1	213
Spring.....	316	57	875	2	3	118	36	90	7	2	1,506
Summer.....	243	28	1,921	4	11	241	56	180	235	6	2,925

There was marked variety of organisms in the heavy October plankton. Diatoms, chiefly *Synedra ulna*, *Pleurosigma*, *Synedra*, and *Nitzschia sigmoidea*, were present in small numbers, but the minute green plants and chlorophyll-bearing Mastigophora were abundant. The most numerous were *Scenedesmus*, *Pediastrum boryanum*, *P. simplex*, *P. tetras*, *Tetraspora*, and *Raphidium*, of the algae, and *Phacus*, *Cryptomonas*, *Chlamydomonas*, *Euglena viridis*, and *E. deses* of the Mastigophora. Ciliate animals included *Carchesium*, *Vorticella*, *Codonella*, and *Halteria*. Rotifers are represented by

Brachionus, *Rotifer tardus*, *Anuræa cochlearis*, and *Asplanchna*, all in small numbers. A few crustacea, chiefly *Bosmina*, and an occasional nematode worm, completes the varied constituents of the October plankton.

November plankton, greatly reduced from the high average of the preceding month, was similarly reduced in variety of organisms. The only diatom was a minute *Synedra*. The small green algæ consisted mainly of *Scenedesmus*, *Pediastrum tetras*, *P. simplex*, and *Pleurococcus*, all in small quantity only. *Euglena* and *Cryptomonas* were the only Mastigophora. Ciliate animals were found in one sample only. These were *Codonella* and *Tintinnus*, in very small numbers. An occasional *Anuræa cochlearis* was all that remained of the October rotifer population, and Crustacea were entirely absent.

Approximately three-fourths of the heavy decrease from October averages was in the green algæ, this group dropping from 1,768 units in October to 242 units in November samples. Relatively heavy decreases are found in the diatoms and the Mastigophora also, as shown in Table 14.

December, 1921, January and February, 1922.—No trip was made to the Des Plaines during December, and none in February. The only winter visit (January 20) found typical conditions for a stream subject to the various fluctuations of season. The water was high, but was completely sealed down with heavy ice, except a narrow strip, 2 to 6 feet wide, and perhaps 500 feet long, in midstream. Only in one or two places could the water be safely approached and inspected.

The current was rapid and the water clear. Small amounts of ice were floating. A moderate amount of green alga (*Cladophora*) was trailing in tufts 7 or 8 inches long from many of the bottom stones where water was about 1 foot deep. There was no odor. Later examination of this alga showed it to be thickly covered with the minute scalelike alga (described on p. 121) and with a few diatoms as well.

The winter plankton averages showed the very light content typical of the average stream during low temperatures of this season, as recorded in Table 13, also in Table 14.

Organisms in the light winter plankton showed little variety. In December a very small *Synedra* was the only diatom. Other minute algæ consisted of *Scenedesmus*, *Pediastrum*, and *Raphidium*, with some unknown minute cells which are found in nearly all plankton collections from a natural stream. Small numbers of *Cryptomonas*, *Euglena*, and *Trachelomonas* represented the Mastigophora, and an occasional specimen of *Carchesium* and of *Vorticella* were the only ciliates found. Larger organisms were practically absent. January

samples were essentially identical, and February samples were again similar.

Relative to oxygen production, the total plankton content averaged, during the three winter months, 88 per cent oxygen producers, and 12 per cent oxygen consumers.

March, April, and May, 1922.—The usual high water of spring was in evidence. Early in April the low margins were flooded, and a low flood plain of 5 or 6 acres a quarter mile above the bridge was completely covered with water. There was no odor, and water was nearly clear. A moderate amount of green alga (*Cladophora*) was trailing in the current and attached to bottom stones. Examination at the laboratory showed that much of this *Cladophora* was well covered with the minute scalelike alga described on page 66. Bottom stones showed a green coating of what appeared to be *Pleurococcus*. A few stones near the surface showed a brownish coating. This consisted chiefly of the diatoms *Surirella* and *Navicula*. Small snails were found under the stones, and many shells of *Planorbis* were found in the drift on shore above the waterline. Midge flies were swarming in the air.

In mid-May the low flood plain was still covered with water, but this in turn was obscured from sight by a tremendous blanket of green alga several acres in extent. This unusual quantity of alga was the most noticeable feature of the Des Plaines at this time. In addition to this surface blanket, the deeper water at the bridge was practically filled with trailing masses 3 to 8 feet long, and certain shallow swift portions of the stream showed a similarly luxuriant growth of green alga a few inches to several feet in length. The alga carpet covered all stones and bottom so completely that only by close inspection could a portion of the actual stone surface be discerned. Two species of *Cladophora* (*C. crispata* and *C. glomerata*) made up the bulk of this great alga growth.

Among the masses of algæ, the snails *Planorbis* and *Limnea* were found in large numbers, together with eggs of *Chironomus* and egg capsules of leech. A few small fish were seen among the algæ, and at a point near the bridge, at a depth of 2 or 3 feet, five or six fish, apparently carp, nearly or quite a foot long were "nosing" the bottom.

Plankton totals in March and April were moderate, but May showed a tremendous increase, as recorded in Table 13, with the cleaner forms heavily predominant.

In the first part of March the plankton showed a rapid but temporary increase in Mastigophora and Ciliata, *Chlamydomonas*, and *Euglena* of the former, and *Vorticella*, *Colpodiura*, *Epistylis*, *Nassula*, and *Codonella*, of the latter, being the chief organisms concerned. This increase was followed by practical absence of these animal forms in the last three of the five collections in this month. April collections

showed a slow recovery of most of the above organisms of the Mastigophora and some of the ciliates. This month also showed the presence of a minute unidentified blue-green alga whose general resemblance to the "Sulphur bacterium" *Beggiatoa* (in the killed material) was quite striking. (See Table 54, in appendix.)

The five collections in May constituted a typical example of the interplay of factors that affect the plankton life in the average polluted stream. The high water incident to spring floods had subsided, temperatures were rising, and the minute plant life of the plankton particularly the microscopic algae, responded to these favorable conditions by a growth (see Table 54) showing 1,000 units the first week, nearly 4,700 the second, 2,900 the third, 3,400 the fourth, then fell to less than 700 units as the month closed. Correlated with this rise and fall is the similar pulse (or cycle) of rotifers, many of which are consumers of these minute plant forms. Rotifers numbered 3 units the first week, then 19, 465, and 734 units on following successive weeks, dropping to 26 units as the month closed. In similar fashion, the Mastigophora described a simultaneous pulse of 80, 627, 272, and 336 units, with a drop to 66 units in the final sample of the month. It is also significant that the Ciliates, which as a class do not find their food in the minute algae, were not abundant, and did not describe the well-defined rise and fall which was so apparent in the case of the rotifers and those smaller organisms used by them as food.

The rotifers chiefly concerned in this pulse were *Brachionus pala*, *B. bakerei*, and *Anuraea cochlearis*, with *Polyarthra*, *Triarthra*, *Synchaeta*, and one or two unidentified ones in comparatively small numbers. The chief constituents of the pulse of minute algae were *Scenedesmus*, *Pleurococcus*, *Botryococcus*, *Actinastrum*, *Pediastrum*, *Tetraspora*, *Raphidium*, and certain minute unidentified cells. *Synedra delicatissima*, *Cyclotella*, *Synedra ulva*, and *Asterionella*, made up the diatom population, and Mastigophora consisted chiefly of *Chlamydomonas*, *Cryptomonas*, *Euglena oxyuris* and *Trachelomonas*.

June, July, and August, 1922.—Conditions noted on the three visits during the summer may be summarized as follows: The stream was down to its normal low level. Water was clear and without odor. Very large amounts of submerged algae were present at all times, though the very extensive alga blanket noted in May had disappeared. Water grasses and slender *Potamogetons* were quite abundant also, practically all of these being submerged. A single specimen of what appeared to be *Monostroma*, a green alga, was found among the *Cladophora* in June, and moderate amounts of the pollutional *Stigeoclonium* were present. Snails, chiefly *Limnaea palustris*(?) and *Planorbis*, were exceedingly numerous among the algae. Small frogs were moderately numerous, and many leeches were found on the undersurface of stones. No fish were observed during the summer.

In August the heavy growth of *Cylindrocapsa* sustained an abundant growth of the minute scalelike alga (see p. 66) and some diatoms. A small amount of *Leptothrix* was found on the alga also. On the whole it seemed that the summer crop of the larger visible organisms, chiefly alga, was nearly or quite equal in number and variety to the heavy yield of late spring already noted.

Summer plankton was likewise heavy, the totals averaging 3,074, 3,001, and 2,752 units for June, July, and August, respectively, thus maintaining throughout the summer almost the high level attained by the late spring (May) average of 3,125 units. (See Table 13.)

In these heavy summer plankton yields, the plants were in the majority, making up two-thirds to four-fifths of the total catch. A few fungus forms were present, but the chlorophyll-bearing, oxygen-producing organisms averaged 83 per cent of the total plankton content. (See Tables 54 and 14.)

The minute green alga was the most conspicuous single group. These microscopic plants made up 50 per cent of the total plankton in June, 73 per cent in July, and the same proportion in August. The most abundant organisms were *Scenedesmus* and *Actinastrum*, these two being especially numerous, and smaller quantities of *Pediastrum simplex*, *P. boryanum*, *Tetraspora*, *Raphidium*, *Botryococcus*, *Calas-trum*, *Pleurococcus*, *Polyedrium*, *Staurostrum*, *Closterium*, *Pediastrum tetras*, *P. pertusum*, and *Dictyosphaerium*.

Next in point of abundance were the Mastigophora and the diatoms, the latter being made up chiefly of a minute *Synedra*, with relatively few of *Navicula*, *Pleurosigma*, and *Surirella*. Mastigophora consisted of *Euglena viridis*, *E. oryzae*, *E. deses*, *Phacus*, *Chlamydomonas*, *Cryptomonas*, and *Trachelomonas*.

In keeping with the above abundance of microscopic plant life, the animal organisms (chiefly rotifers and crustacea) that feed on these, were noticeably abundant. As shown in Table 54, rotifers were very numerous the first part of June, decreased to small values in latter June and first half of July, then showed a second rise, with a fall to moderate numbers again during August. In this latter month, however, the crustacea were especially numerous. Beginning with low values in June, these organisms showed an increase as the rotifers decreased, maintained moderately high values in July while rotifers rose and fell, and increased to their maximum content in August during which period rotifers were found in moderate numbers only. It may be that a food relation exists between the crustacea and the rotifers.

The principal rotifers present were *Brachionus pala*, *B. angularis*, *Anuraea cochlearis*, *A. tecta*, and *Polyarthra*, in June; *B. angularis*, *Polyarthra*, and *A. cochlearis*, in July; and essentially the same ones in August. Crustacea in June were *Cyclops*, *Bosmina*, and naupleii,

and the same forms in July and August, with the addition of *Daphnia* in the latter month.

Ciliates were not abundant. They attained moderate abundance in only 3 of these 13 summer collections. This fact finds its probable explanation in the prevailing rapid movement and turbulence of the water, these conditions being unfavorable, as a rule, to the development of most of the ciliates. The principal ciliates present were *Codonella*, *Tintinnus*, *Carchesium*, and *Vorticella*. It should be remembered, in this connection, that small colonies of the stalked colonial ciliates *Carchesium*, *Epistylis*, and *Vorticella*, were frequently found on the alga collected at this station.

Summary.—This brooklike river is characterized by wide fluctuations in volume, and by great extremes of plankton yield. The very low plankton content of winter and early spring is followed by a sudden increase in late spring, and this heavy yield is maintained throughout the summer. The most noticeable feature of the stream is the extraordinary quantity of green filamentous alga which carpets the stream bed, and practically fills the channel from late spring to late autumn. Conditions are ideal for an abundant supply of oxygen on account of this algæ, on account of the physical conformation of the channel, the clearness of the water, and finally by reason of the very heavy predominance of minute chlorophyll-bearing organisms in the plankton.

The index organisms of the plankton averaged 15 per cent for pollution and 85 per cent for cleaner water during autumn, and 45 per cent for pollution and 55 per cent for cleaner water during winter. The spring months showed 20 per cent for pollution and 80 per cent for cleaner water, and summer collections averaged 11 per cent for pollution and 89 for cleaner water. The average for the entire 11 months stood 14 per cent indicating pollution and 86 per cent showing cleaner water.

These figures seem to indicate that most of the sewage pollution in the Des Plaines River has been well reduced during the 20 to 30 miles passage through a shallow channel. Also the very high proportion of cleaner-water organisms in late spring and summer would seem to indicate the beneficial rôle of the great quantities of submerged plants then prevalent, this benefit resulting presumably by reason of the excess oxygen provided by these plants and the degree of purification or reduction of organic matter made possible by these stores of oxygen.

Another matter of seeming like importance is the heavy predominance, in the plankton, of the chlorophyll-containing organisms, with their oxygen-producing possibilities. Reference to Table 14 will show that, in the averages for the four seasons, these chlorophyll-bearing organisms (diatoms, blue-green and green algæ, and Masti-

gophora) constitute 94, 85, 91, and 83 per cent, respectively, of the average total plankton for autumn, winter, spring, and summer and those forms which lack chlorophyll (the fungi and the animals) constitute 6, 15, 9, and 17 per cent, respectively, of these same totals.

The plankton picture of the Des Plaines may be further simplified by stating the average content as based on all the 47 weekly collections taken over a period of 11 months. Such an average shows a total plankton of 1,469 cubic standard units per cubic centimeter of water, and this total is made up of over 87 per cent chlorophyll-bearing organisms and about 13 per cent of such organisms as lack chlorophyll. In a word, the heavy plankton of the Des Plaines brings to the sewage-laden floods from the drainage canal nearly seven times the quantity of oxygen producers as of oxygen users. Such a contribution would seem to indicate that the Des Plaines not only dilutes these heavily polluted waters, but also seeds them with large numbers of such organisms as will contribute their output of excess oxygen at a critical time and place in the ensuing program of natural purification.

STATION 288, RUBY STREET BRIDGE, JOLIET

A mile or more above this point the drainage canal merges with the Des Plaines River, the channel of which had been deepened and widened to receive the large volume of water. Through the town of Joliet this channel is confined between vertical walls of concrete, the stream thus formed being about 160 feet wide. The water flows rapidly for most of the distance between these walls, but at Ruby Street this speed is considerably slackened by the Jackson Street dam, about 250 yards below, where the municipal power plant is located. Here the portion of water which is not utilized in the production of power passes over a spillway about 12 feet high and the stream proceeds on its way between vertical walls for another mile or more.

The bottom is apparently well covered with heavy riprap. This condition, together with a current brisk enough to prevent much deposit of suspended matter, made it practically impossible to secure any bottom sediment at this point. After repeated failures during our first visits no further attempts were made.

The usual appearance of the stream here is that of a grayish, dirty water, with moderate amounts of flocculent material floating in masses varying in size from that of a wheat grain to that of a walnut or larger. These masses seem to be equally abundant at all depths of the water, or as far toward the bottom as one can see. Their specific gravity is practically the same as that of water, for a given mass will float at the surface or at various depths, apparently following

all the small currents and countercurrents incident to the briskly moving water.

There is little floatage on the water surface except small amounts of oily skum and small dead fish, the latter sometimes reaching large numbers. There is a moderate odor of sewage except in the coldest weather. The water is 12 to 20 feet deep, with no shallow margins.

September, October, and November, 1921.—Late in September the briskly flowing, grayish water had a moderately strong odor of sewage. Small floating masses of the stalked ciliates *Carchesium* and *Epistylis* were fairly abundant and the grayish cast of the stream as a whole was found to be due chiefly to the multitudes of minute fragments of these same organisms. Small amounts of algæ (the blue-green *Oscillatoria* and the green algæ *Cladophora* and *Stigeoclonium*) were growing on or near the wall. Considerable amounts of *Epistylis* in good-sized colonies were attached to these algæ. (See Table 15.)

TABLE NO. 15.—Bottom conditions, water surface, and stream margins

RUBY STREET BRIDGE (STATION 286)

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921 Sept. 27	(1) Vile odor; but little sediment obtained, owing to bottom of heavy rip-rap; (2) <i>Epistylis</i> , <i>Carchesium</i> , and <i>Rotifer tardus</i> very abundant; old ice tongs, recovered from bottom, thickly covered with <i>Carchesium</i> and <i>Epistylis</i> . No sediment obtained because of depth of water and rocky bottom.	(1) Sewage odor moderately strong; current moderate; (2) moderate amount of <i>Carchesium</i> and small amount of <i>Epistylis</i> .	(1) Perpendicular concrete wall; no shallow margins; (2) no shore nor emergent plants; small amount of <i>Oscillatoria</i> , <i>Cladophora</i> , and <i>Stigeoclonium</i> ; <i>Epistylis</i> growing on these algæ.
Nov. 20	No sample obtained because of depth of water and rocky bottom.	(1) Sewage odor moderate; (2) moderate amount of <i>Carchesium</i> , <i>Saprolegnia</i> , and bits of paper.	(1) Sewage odor; (2) moderate amount of <i>Phormidium</i> , <i>Sphaerotilus</i> , and <i>Cladophora</i> growing on wall; <i>Carchesium</i> abundant on algæ; small school of minnows, probably "shiners," creeping along shore close to surface, going upstream. (The "shiner" is tolerant of sewage.)
1922 Jan. 20	No sample obtained on account of depth and rocks.	(1) Smooth; moderate current; no odor; (2) no floatage. See column iii.	(1) No odor; (2) unknown fungus abundant; <i>Sphaerotilus</i> and <i>Leptomitris</i> in small amounts; small amount of <i>Cladophora</i> and <i>Pseudocella</i> ; no fish seen.
Apr. 7	No sample obtained.....	(1) Slight sewage odor; (2) no gross floatage.	(1) Slight odor; (2) no growth along margins; large amounts of <i>Leptomitris</i> and small amounts of <i>Achiya</i> and <i>Sphaerotilus</i> in floating masses, pea to walnut in size.
May 13	No sample obtained.....	(1) Noticeable odor; (2) many dead fish, about 250 (estimated) per minute, passing given point; large amount small floating (submerged) masses of <i>Carchesium</i> (very abundant), <i>Sphaerotilus</i> (very abundant), <i>Cladophora</i> (small amount).	(1) Moderate odor; (2) large amount of <i>Stigeoclonium</i> and <i>Sphaerotilus</i> along west margin near small street sewer.

TABLE NO. 15.—Bottom conditions, water surface, and stream margins—Continued

RUBY STREET BRIDGE (STATION 200)—continued

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1922			
June 26	No sample.....	(1) Odor of sewage; (2) few dead fish, small amount oily scum, large amount small flocculent masses, probably <i>Carchesium</i> .	(1) Odor of sewage; (2) no plant life along margin.
July 31	No sediment obtained.....	(1) Water high; moderate sewage odor; (2) few dead fish, and small amount oily scum; small amounts of <i>Carchesium</i> and <i>Sphaerotilus</i> .	(1) High water; moderate sewage odor; (2) no plants along margins.
Aug. 29	No sediment obtained.....	(1) Looked clean; slight odor; (2) small amount of <i>Epistylis</i> and <i>Sphaerotilus</i> ; no fish floating.	(1) Slight sewage odor; (2) no plant life along margin.

Repeated efforts to obtain bottom mud revealed only a rough rocky bottom which at the most favorable place was at a depth of about 12 feet. The sampler fortunately encountered an old pair of ice tongs which had evidently been submerged a long time, being thickly covered with a grayish, slimy coating. The material scraped from these tongs was therefore accepted as an index of conditions at this 12-foot depth. This material consisted almost wholly of *Carchesium* and *Epistylis*, in large, richly branched colonies. Enmeshed and anchored among the minute stalks of these ciliates were large numbers of the pollutional *Rotifer tardus*. The entire mass of material adhering to the ice tongs had a vile odor.

In late November conditions were much the same as to floating masses and the grayish appearance of the stream. The floating masses, in moderate abundance, included the stalked ciliate *Carchesium*, the fungus *Saprolegnia*, and scraps of paper.

At the west margin the blue-green alga *Phormidium* was growing, attached to the wall (which was partly broken down at one point, enabling the visiting biologist to reach the edge of the water). *Sphaerotilus*, a fungus characteristic of sewage, and the green alga *Cladophora* were also found here, with a heavy growth of the ever-present *Carchesium* on the alga in large whitish masses.

A small school of little fish about 2 inches long was observed slowly working their way upstream. The fish were at the extreme west edge, and were very close to the surface. They were presumably "shiners," a species of minnow that is tolerant¹ of sewage pollution.

Relative to the unexpected appearance of these small fish, it is to be noted (1) they are tolerant of sewage pollution; (2) they were on that side of the stream which, a mile or more above, receives the Des

¹ Bull. Illinois Natural History Survey, Vol. XIII, Art. VI, p. 154.

Plaines River. This stream had recently been considerably flooded, and was still high at the time of this observation. These fish may have been brought down by flood water; (3) they were "hugging the surface," and the water was cold (6° C.), and therefore capable of containing more oxygen than usual, with bacterial demand on oxygen less meantime because of lessened bacterial activity.

The autumn plankton.—The autumn plankton averaged 1,019 cubic standard units, of which amount the index organisms averaged 598 units, these in turn being 200 units of the pollutional forms and 398 units of the cleaner-water forms. The autumn average of chlorophyll-bearing, oxygen-producing organisms was 83 per cent of the total plankton, the diatoms (chiefly from Lake Michigan) alone constituting nearly 40 per cent of this oxygen-producing group.

Specific organisms prevalent in this autumn plankton were as follows: *Synedra*, *Melosira*, *Tabellaria fenestrata*, and *Fragilaria*, in practically every sample, were the leading diatoms. *Asterionella* and *Navicula* were also present in more than half the samples. The blue-green algae were not abundant. Green algae showed great variety, but only a few (*Pleurococcus*, minute unknown cells, *Scenedesmus*, *Pediastrum*, and *Botryococcus*) were all present in half or more of the samples, while some half dozen other kinds appeared in one or two samples each. Flagellates were few, and seemed to be of minor importance. (Table 16.)

TABLE NO. 16.—Classification of plankton organisms
STATION 286, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1901											
October.....	262	—	519	0	—	86	130	12	—	40	.....
November.....	276	36	277	12	1	66	50	0	0	19	.....
December.....	186	16	287	11	—	24	41	7	10	17	.....
1902											
January.....	50	44	123	49	—	19	54	—	—	3	.....
February.....	93	51	100	26	—	1	46	—	—	4	.....
March.....	127	73	190	20	1	45	61	3	—	23	.....
April.....	119	69	269	4	—	9	194	—	—	86	.....
May.....	307	25	215	9	—	80	272	2	4	11	.....
June.....	76	68	222	—	—	28	74	—	—	27	.....
July.....	86	80	251	22	1	13	77	3	9	25	.....
August.....	26	83	262	13	9	56	79	2	19	40	.....
Averages:											
Autumn.....	246	30	435	10	—	74	86	6	—	52	1,019
Winter.....	124	37	164	26	—	12	55	2	4	9	422
Spring.....	271	49	346	17	—	86	180	2	2	24	614
Summer.....	66	46	257	12	1	84	75	2	9	26	527

Ciliates were nearly constant in their occurrence, although this group constituted, on an average, only 9 per cent of the total plankton, being greatly exceeded by two other groups, the diatoms (constitut-

ing 34 per cent) and the green algae (43 per cent), in these autumn averages. The pollutional form *Carchesium* appeared in every sample, and forms of similar sanitary status, *Epistylis*, *Colpidium*, *Vorticella*, and *Paramecium*, all pollutional organisms, were found in about half of the samples. *Rotifer tardus*, a pollutional form, appeared in three samples, and the cleaner-water rotifer *Anuraea cochlearis* was found once. Crustaceans were absent. Nematode worms were occasional.

December, 1921, January, and February, 1922.—Only one visit was made to this station during these winter months. On January 20 the stream presented the usual grayish appearance, due to the large amount of minute floating masses. Larger masses, the size of a pea to that of a walnut, were floating in abundance. These consisted chiefly of an unknown fungus, together with small amounts of a well-known sewage fungus, *Leptomitus*. Along both margins of the stream dirty-white masses of funguslike material were attached to the wall, or to stones. The chief constituent of these masses was the fungus *Sphaerotilus*, the strands of which were to a great extent invested with a rather firm zoogloea-like material of unknown origin. Small bits of the green alga *Cladophora*, together with traces of the bryozoan *Paludicella* were also taken in these samples collected from the stream margin.

There was no noticeable odor at this time. Temperature of water was 0° C. No fish were seen. Surface of the stream was practically free of floatage.

The winter plankton.—Inspection of the data for the nine autumn samples indicates the following averages: Total plankton, 1,019 units; index organisms, 598; pollutional forms, 200; cleaner forms, 398.

Similar inspection of the 12 samples taken during the winter indicate the following averages: Total plankton, 436 units; index organisms, 182 units; pollution forms, 99; cleaner forms, 83.

It is apparent from these figures that the average total yield in winter is less than half (43 per cent) of the yield in autumn, and that the winter index organisms are 30 per cent, the pollutional forms are 49 per cent, and the cleaner forms are 21 per cent of the respective autumn averages. Of these last two groups the pollution forms have apparently resisted, to best advantage, the unfavorable condition of low temperature incident to winter, having been reduced only 51 per cent from the autumn averages, whereas the cleaner-water forms have been reduced by nearly 80 per cent.

The relative abundance, in terms of volume, of the various groups of organisms in this light winter plankton is indicated in Table 16 where it will be noted that diatoms, green algae, and ciliates, the three largest groups, constitute 28 per cent, 53 per cent, and 13 per cent, respectively, of the total plankton average.

The predominating organisms in the winter plankton were *Asterionella*, *Synedra*, and *Tabellaria fenestrata* of the diatoms, blue-green algae consisted of minute fragments, green algae were chiefly *Pleurococcus*, unknown green cells, and *Scenedesmus*, the leading fungus was *Sphaerotilus*, and flagellates were only occasionally present in small amount. The pollutional ciliates *Carchesium* and *Colpidium* dominated the situation, being present in every sample, with *Vorticella*, *Paramacium*, and *Epistylis* occasional. The pollutional rotifer *Actinurus* and the cleaner-water forms *Anuraea cochlearis* and *Brachionus doreas* were found in one sample each, as was also the crustacean *Cyclops*.

March, April, and May, 1922.—Two trips to this station April 7 and May 12, respectively, found the stream in its usual form, grayish water, with heavy content of small flocculent masses floating at various depths. The odor of sewage was slight in April, but was quite noticeable in May. Surface floatage was absent in April, but in May large numbers of small dead fish were floating.

In April there was no growth along the margins, and the large amount of flocculent masses floating at various depths consisted mainly of *Leptomitris* with small amounts of *Sphaerotilus* and *Achlya*, all of them typical sewage fungi. In May rather large amounts of *Stigeoclonium* (a pollutional or tolerant green alga), and of *Sphaerotilus* were found attached along margin, and the flocculent floating masses were chiefly *Carchesium*, and *Sphaerotilus* with small amounts of the green alga *Cladophora* which was so abundant in the Des Plaines above the mouth of the canal.

The spring plankton.—Moderate values in March increased somewhat in April and reached high values in May, when the average plankton yield was nearly double that of March. The 13 weekly samples averaged 816 units of total plankton as compared to the winter average of 432 units. Pollutional forms predominated.

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TABLE No. 17.—Summary of plankton findings for all months

AVERAGES AT STATION 288

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms				Total organisms			
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner		
1921												
October.....	887	265	1,152	9,700	881	23	242	6	202	828	422	
November.....	766	144	910	18,100	754	42	102	13	190	294	418	
December.....	445	99	544	20,400	434	2	97	11	80	125	340	
1922												
January.....	339	70	409	12,500	290	13	58	48	98	83	223	
February.....	290	75	364	9,800	242	1	74	26	124	45	176	
March.....	424	129	553	14,000	392	42	87	32	156	62	335	
April.....	560	228	788	30,900	566	4	224	4	219	83	485	
May.....	756	340	1,096	13,100	747	28	312	9	269	223	605	
June.....	369	134	503	16,700	369	14	120	0	112	79	311	
July.....	412	137	551	15,300	390	15	124	22	83	99	370	
August.....	356	197	553	9,700	343	31	146	13	156	118	279	
Averages for 11 months.....	508	165	673	16,290	492	21	144	17	154	158	361	

The most important groups of organisms in a volumetric sense were (as in autumn and winter) the diatoms, the green algæ, and the ciliates. These three groups constituted 33 per cent, 30 per cent, and 21 per cent, respectively, of the total plankton average. The chlorophyll-bearing oxygen-producing organisms collectively made up more than 70 per cent of the total plankton yield in these spring samples. (See Tables 8 and 16.)

The leading organisms in the spring collections were as follows: *Asterionella* was the leading diatom, being found in every collection. *Synedra* and *Tabellaria flocculosa* each appeared in about half of the samples, with *Fragilaria* and *Navicula* present a little less often. Blue-green algæ were infrequent. Of the green algæ, *Pleurococcus* and minute unknown cells resembling *Pleurococcus* somewhat were found in all samples. *Scenedesmus* and *Tetraspora* were occasional. The flagellates *Cryptomonas* and *Euglena* were similarly infrequent. Ciliates were present in force, the pollutional forms *Colpidium* and *Carchesium* appearing in every sample, with the associated pollutional organisms *Epistylis* and *Vorticella* in about half the samples. The pollutional *Rotifer tardus* appeared in one sample. A single specimen of crustacea (*Bosmina*) was found.

June, July, and August, 1922.—In late June the grayish water gave off a perceptible odor of sewage. A few dead fish were floating on the surface and a large amount of very small flocculent masses was to be seen floating at various depths. This was probably *Carche-*

sium, *Epistyles*, fungus, etc., but the sample collected was lost by breakage. No algæ were growing in the margins. No living fish were seen. In July practically the same conditions prevailed.

The final visit, late in August, found the stream presenting its usual picture—a grayish water, with moderate sewage odor, flocculent matter (not abundant at this particular time) floating in small masses at various depths in the brisk current. There was little or no surface floatage or débris. No living fish were to be seen, and there were practically no algæ or other plant life along the margin. (See Table 15.)

The summer plankton.—In June the total plankton averaged 503 cubic standard units, less than half the high average of the preceding month. July and August collections showed about the same plankton content as June.

The 13 summer samples averaged 537 units of total plankton. The index organisms, averaging 212 units, showed an average of 112 units of pollutional forms and 100 units of the cleaner-water forms.

As in the three preceding seasons, the leading groups of organisms, expressed in volume, were the diatoms, the green algæ, and the ciliates, making up 12 per cent, 48 per cent, and 14 per cent, respectively, of the total plankton average. (See Table 16.) The greatest divergence is noted in the diatoms, which, forming 33 per cent of the spring total plankton, are now reduced to only 12 per cent in the summer catches, this drop being probably due to the well-known preference of diatoms as a class for the cooler portions of the year. Oxygen-producing organisms made up about 75 per cent of the average total for the summer months.

Predominating organisms in the summer plankton were essentially as follows in the 13 weekly samples taken: *Synedra* in eight samples, and *Navicula* in seven were the leading diatoms. The two *Tabellarias*, *Melosira*, and *Fragilaria* were all present occasionally. Blue-green algæ were not abundant. Of the green algæ, *Pleurococcus* and minute unknown cells were found in all samples, *Scenedesmus* in eight, and *Tetraspora* and *Celastrum* each in three. *Pediastrum*, *Staurastrum*, and one or two others were occasional.

Fungi were practically absent from the summer collections. The rhizopod *Diffugia* was found in four samples. Of the flagellates, *Euglena*, *Cryptomonas* and *Chlamydomonas* were found in two or three samples each. Ciliates were much more numerous, the pollutional forms, *Carchesium*, *Colpidium*, and *Vorticella* appearing in nearly all the samples. *Epistylis* and *Paramacium* were occasional.

The larger plankton life was represented by an occasional rotifer (usually *R. tardus*) and by *Cyclops*, the latter in one sample only. Nematode worms also were occasional.

Summary.—(1) The briskly flowing water is always grayish in color, and, except in the coldest weather, gives off a moderate odor of sewage.

(2) Minute suspended matter is always present, and usually consists chiefly of small bits of *Carchesium*, *Epistylis*, *Sphaerotilus*, *Lep-
tomitus*, etc.

(3) Larger masses of these same growths are usually floating and are frequently abundant. Masses of the same organisms are moderately abundant along the margin, and the only sample obtained from the bottom (the old ice tongs) showed a very heavy growth of these same organisms. It seems obvious that the never-failing supply noted in the floating and suspended matter has its source in the growths along the margin, and the similar growths that apparently carpet the bottom stones.

(4) Small amounts of algæ (chiefly *Oscillatoria*, *Stigeoclonium*, and *Cladophora*) were sometimes found along the margin, especially in the spring. As summer advanced these algæ practically disappeared, to reappear at times during autumn and winter.

(5) Living fish were seen once (but only once) during 11 months' observations, and this was at a time of high water in the Des Plaines River before the canal emptied into it—a mile above this station.

(6) Study of the plankton data shows that organisms indicating heavy pollution are relatively abundant most of the time. Taking the monthly averages (shown in Table No. 17) as a basis, it is to be noted that pollutional organisms exceed the cleaner-water forms during 7 of the 11 months, but the figures for the entire year show almost identical values (49 per cent and 51 per cent) for these two classes of organisms.

(7) This practically equal division of the known index organisms—half indicating heavy pollution and half indicating relatively clean water—is explainable on the grounds that the lake water required to flush the sewage through the canal brings with it the greater portion of these clean-water organisms, chiefly diatoms. The pollutional organisms are due to the sewage, and, to some extent, to the moderately polluted Des Plaines River. It would seem reasonable that when this sewage shall have had sufficient time to attain its maximum degree of decomposition, then the plankton organisms which thrive in such an environment of pollution (chiefly those that feed on bacteria) will show perceptible increase in number.

STATION 286. BRANDON BRIDGE

Four miles above this point the drainage canal empties into the Des Plaines River. After turbulent passage (including a 12-foot fall over the Jackson Street Dam in Joliet) for about 2 miles between vertical concrete retaining walls which limit its width to about 160 feet, the waterway widens to 500 to 700 feet, without walls, a mile or two above Brandon Bridge. There is corresponding decrease in depth, but the gradient is steep and the water turbulent. On arriving at the bridge the channel narrows to about 300 feet, and increases in depth. There is rapid turbulent flow at this point, and for 8 or 10 miles downstream.

A shallow overflow or by-pass on the right side passes under a continuation of Brandon Bridge proper and rejoins the main stream 40 or 50 yards below. This by-pass, 15 feet wide and only a few inches deep, affords the only shallow-water conditions available at this sampling station. The bottom is stony, and water turbulent. A luxurious growth of *Arum* and of weeds occupies large portions of the low banks of both main stream and by-pass.

September, October, and November, 1921.—Three visits were made during the autumn. In late September there was moderate odor of sewage, the turbulent water was grayish, due largely to abundance of minute suspended matter and to small bits of the stalked ciliates, *Carchesium* and *Epistylis*. Small mats of the pollutional green alga *Stigeoclonium* were floating downstream with larger masses of the stalked ciliates named. Attached along the margins and in the shallow by-pass, or to emergent sticks, grass, or other support, were large amounts of *Stigeoclonium*, the sewage fungus *Sphaerotilus*, also *Carchesium* and *Epistylis*. Some of these masses harbored large numbers of *Rotifer tardus* and a few tubifex worms. A blue-black, slippery growth of *Oscillatoria* was abundant on the marginal stones which were submerged, probably every night, by the increased volume of water due to greater flow through the turbines of the power house. (See Table 18.)

The swift current prevented the deposit of bottom sediments except in an occasional eddy near shore. Sediment obtained from these sources, in late September was black, granular, and had distinct sewage odor. *Carchesium*, *Epistylis*, and *Sphaerotilus* were present in relatively large amounts. These growths were in all probability scraped off of the stones and riprap on the bottom and sides of the canal, as the mud samples were being hauled ashore. Many *Rotifer tardus* were associated with these attached organisms.

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TABLE NO. 18.—Bottom conditions, water surface, and stream margins

BRANDON BRIDGE (286)

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921 Sept. 26	(1) Black, granular, with sewage odor; (2) <i>Carchesium</i> , <i>Epistylis</i> , and <i>Sphaerotilus</i> (all attached organisms) in large amounts; many rotifers (<i>R. tardus</i> only) associated with these growths.	(1) Rapid, turbulent water, grayish in color; surface broken by eddies and currents; moderate odor of sewage; (2) The colonial ciliates <i>Epistylis</i> and <i>Carchesium</i> in moderate abundance floating, also attached to any available support near surface; small mats of the green alga <i>Stigeoclonium</i> floating.	(1) Thorough mixing to edges of stream; odor of sewage; (2) Arum and weeds along margin; large amounts of <i>Stigeoclonium</i> , <i>Carchesium</i> , <i>Epistylis</i> , and <i>Sphaerotilus</i> trailing from any available support (sticks, emergent plants, etc.) along margins; blue green alga <i>Phormidium</i> and <i>Oscillatoria</i> abundant on marginal stones and harboring many <i>Rotifer tardus</i> ; <i>Spirogyra</i> in moderate amounts, and small amounts of <i>Ulothrix</i> .
Nov. 30	No bottom samples obtained.	(1) Turbulent, grayish, with moderate odor of sewage; (2) large total amount of small masses of <i>Carchesium</i> and <i>Sphaerotilus</i> , with some <i>Epistylis</i> , floating.	(1) Grayish, turbulent water; no shallow margins; odor of sewage; (2) brownish, felt-like layer of <i>Phormidium</i> abundant on marginal stones with many diatoms (<i>Navicula</i>) associated. The attached growths (<i>Sphaerotilus</i> , <i>Stigeoclonium</i> , <i>Carchesium</i> , and <i>Epistylis</i>) abundant.
1922 Jan. 20	(1) Black, granular, with very disagreeable odor; (2) large amount of <i>Carchesium</i> and of fungus, chiefly <i>Leptomitrus</i> ; 1 liter of mud yields about 100 tubifield worms.	(1) Turbulent, grayish, but with no perceptible odor; (2) large amount of <i>Leptomitrus</i> and of another fungus (unidentified); small amount of ice floating.	(1) Ice on marginal stones; no odor; (2) <i>Leptomitrus</i> , <i>Sphaerotilus</i> , and another fungus (unidentified) all abundant; stalks of <i>Carchesium</i> and <i>Epistylis</i> , mostly without "heads"; the green alga <i>Cladophora</i> in small amount.
Apr. 7	(1) Black, granular, with strong odor; (2) tubifield worms, about 2,600 in 1 liter of mud; small numbers egg capsules of these worms indicating reproduction; small amounts <i>Leptomitrus</i> and <i>Sphaerotilus</i> .	(1) Water higher than usual, turbulent, grayish, with slight sewage odor; (2) large amount of fungus floating, most of it being <i>Leptomitrus</i> , the remainder <i>Sphaerotilus</i> .	(1) High water; slight sewage odor; (2) moderate abundance of <i>Leptomitrus</i> and <i>Sphaerotilus</i> attached along margin; no alga.
May 13	(1) Black, granular, with tarry odor; (2) 4,600 tubifield worms in 1 liter of mud; some egg capsules present, also small amounts of <i>Carchesium</i> .	(1) Turbulent, grayish, with moderate odor of sewage; (2) <i>Epistylis</i> and <i>Carchesium</i> floating in moderate abundance; small amounts of the green alga <i>Stigeoclonium</i> ; few dead fish floating.	(1) Thousands of dead minnows stranded along margin; noticeable odor from these and from sewage, (2) <i>Carchesium</i> abundant, but much of it without "heads"; <i>Stigeoclonium</i> in small amount; diatoms on submerged sticks; no coating of alga on marginal stones.
June 23	(1) Black, coarsely granular, with tarry stinking odor; (2) 850 tubifield worms, and a few egg capsules of same; <i>Carchesium</i> in small amount, much of it headless; a few small sinistral snails.	(1) Turbulent, grayish, with slight odor of sewage; (2) large amount <i>Carchesium</i> , and some <i>Epistylis</i> ; a few small dead fish floating.	(1) Turbulent, grayish, with slight odor; (2) Arum, "cat-tails," and weeds; <i>Stigeoclonium</i> abundant; heavy growth of <i>Phormidium</i> , with many diatoms (<i>Navicula</i>) on stones also mats of <i>Oscillatoria</i> with many <i>Rotifer tardus</i> associated; large amounts of <i>Carchesium</i> and some <i>Sphaerotilus</i> .
July 31	No bottom sample obtained on account of rocks.	(1) Water high, turbulent, grayish, with slight odor; (2) unusual abundance of <i>Epistylis</i> and <i>Carchesium</i> floating, together with some <i>Sphaerotilus</i> and <i>Stigeoclonium</i> .	(1) Water high; slight odor of sewage; (2) Arum and weeds along margin; the blue-green alga <i>Phormidium</i> in mats on marginal stones; <i>Carchesium</i> , <i>Epistylis</i> , and <i>Sphaerotilus</i> abundant.

TABLE No. 18.—Bottom conditions, water surface, and stream margins—Continued

BRANDON BRIDGE (200)—Continued

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1922 Aug. 20	(1) Black, granular, with tarry nauseous odor; (2) 5,500 tubifid worms; large amount of <i>Carchesium</i> , with <i>Leptomitris</i> , <i>Sphaerotilus</i> , and <i>Epistylis</i> in smaller quantity; very large numbers <i>Rotifer tardus</i> associated with the above growths; moderate amount of an unknown coarse, unbranched, leaflike green alga, with slender base and gradual enlargement to distal end.	(1) Water h' h, turbulent, grayish, with slight odor; (2) <i>Epistylis</i> and <i>Carchesium</i> in moderate amounts, but <i>Epistylis</i> abundant in shallow by-pass; tufts of <i>Stigeoclonium</i> floating; large amount of <i>Leptothrix parvula</i> on stalks of above organisms.	(1) Turbulent; grayish with suspended matter; slight odor; (2) <i>Epistylis</i> and <i>Sphaerotilus</i> abundant, also <i>Phormidium</i> on marginal stones; the green alga <i>Ulothrix</i> in moderate amount; <i>Rotifer tardus</i> abundant among tangles of the above growths; <i>Stigeoclonium</i> in small amount.

The plankton of October showed, for the index organisms, a light preponderance of pollutional forms. The total plankton showed a heavy majority of oxygen producers. (See Tables 8 and 19.) The November plankton differed slightly in containing a preponderance of cleaner-water forms in the index organisms.

Predominant organisms of the plankton in October were *Tabellaria fenestrata*, *Synedra*, and *Melosira* of the diatoms, and *Scenedesmus*, *Botryococcus*, *Pediastrum*, *Celastrum*, and *Pleurococcus* of the minute green algæ. *Euglena viridis* represented the *Mastigophora*, *Colpidium*, *Carchesium*, *Epistylis*, and *Vorticella* the ciliates, and *Rotifer tardus* was the only rotifer found.

In November the apparent situation at this station had changed but little. The turbulent, swirling water was grayish in color, and a moderate odor of sewage was noticeable. *Carchesium*, *Epistylis*, and *Sphaerotilus* were floating in numerous small masses, but in rather large total amounts. Margins and shallow by-pass again showed large amounts of the organisms mentioned above, attached and trailing in the current. The green alga *Stigeoclonium* was also abundant. Examination at the laboratory showed that a waxy, structureless, dirty-white material, of unknown origin and nature, invested the basal portions of stalks and branches of these attached organisms, including portions of the alga. A thick, brownish feltlike layer of blue-green algæ (chiefly *Oscillatoria* and *Phormidium*) was very abundant on the marginal stones, and large numbers of the diatom *Navicula* were associated with these alga-mats.

No bottom samples could be obtained on the November trip to this station.

December, 1921, January and February, 1922.—The only trip to this station during the winter months was made January 20, 1922. A small amount of snow was on the ground, and weather was cold

enough to freeze in a few moments the wet rope of the mud-sampling apparatus after withdrawal from the water. A little ice coated the marginal stones, and small cakes of ice were floating. Water was slightly grayish in color and turbulent. No odor was perceptible.

The water showed a rather large amount of funguslike growths floating in small masses. This consisted chiefly of *Leptomit*, together with another unidentified fungus. Attached to stones, grass stalks, and weeds in the margin, or in the shallow by-pass, were rather large amounts of the sewage fungus *Sphaerotilus*, of the unknown fungus, and also of *Leptomit*. *Carchesium* and *Epistylis* were moderately abundant, but the greater part of these stalked organisms were without "heads," and consisted chiefly of the naked stalks only. The unknown waxy, zooglea like material invested the basal portions of these stalks to a marked extent. Small tufts of the green alga *Cladophora* were seen occasionally.

Bottom sediments were black, with nauseous odor, and contained large amounts of *Carchesium* and *Leptomit*, probably scraped from bottom rocks by the mud sampler. One liter of mud contained about 160 tubificid worms. (See Table 18.)

Plankton content was relatively light during the winter months. Majority of the index organisms were of the pollutional sort. Oxygen-producing organisms were predominant in the total plankton even during these winter months. (See Tables 8 and 19.)

TABLE NO. 19.—Summary of plankton findings for all months
AVERAGES AT STATION 206-7

Date	Plankton catch, cubic standard units in 1 c. c. of water										
	Total catch				Total organisms				Total organisms		
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner	
1921											
October.....	818	143	961	11,600	818	16	128	0	307	294	361
November.....	643	131	774	22,800	643	10	122	0	132	277	364
December.....	519	66	585	2,200	500	11	56	19	60	47	181
1922											
January.....	264	137	421	18,200	234	14	123	50	114	42	264
February.....	166	170	336	16,200	165	0	170	3	138	59	141
March.....	478	171	649	16,800	478	7	164	0	181	51	416
April.....	605	185	790	39,700	605	58	97	0	183	35	362
May.....	745	214	960	15,000	743	25	189	3	189	116	656
June.....	360	192	542	18,700	348	34	187	2	135	58	350
July.....	326	192	518	12,200	326	49	144	0	102	60	357
August.....	319	177	496	12,200	315	16	167	4	183	89	223
Averages for 11 months.	478	149	637	18,520	470	21	126	7	162	100	352

It is to be noted in passing that the winter plankton is a reduction of nearly 50 per cent as compared with the average yield of autumn. Of the autumn totals, the oxygen producers constituted 86 per cent, but the percentage of these organisms fell to an average of 69 for the

three winter months. Percentage of pollution organisms (based on quantity of index organisms) averaged 44 per cent for pollution and 56 per cent for cleaner water in autumn, whereas these respective percentages averaged 68 and 32 in the three winter months.

Predominating plankton organisms during the winter were the diatoms *Synedra*, *Asterionella*, *Tabellaria*, and *Fragilaria*; the green algæ *Pleurococcus*, *Scenedesmus*, *Tetraspora*, and certain unknown minute cells; the fungus *Sphærotilus*; a very few flagellates occasionally, and practically continuous presence of the pollutional ciliates *Carchesium* and *Colpidium*, with *Epistylis* a close second and *Vorticella* of frequent occurrence. Rotifers and crustacea rarely appeared in these winter samples.

March, April, and May, 1922.—In early May the water was a little higher than usual, possibly due to high water in the Des Plaines. Slight odor of sewage was noticeable. The water was grayish, and flocculent matter in masses varying in size from pea to walnut was floating in large amount. Most of this was *Leptomitius*, a fungus of well-known sewage preference, with moderate amounts of *Sphærotilus*, another sewage fungus. These two fungi were also found in moderate abundance attached to any kind of support available along the margins. No algæ, either green or blue green, were found along margins or on marginal stones.

Bottom sediment was secured just below the bridge, at a depth of about 10 feet. Sediment was black, with strong tarry odor. It was not pasty, but was made up chiefly of large granules, or minute lumps, which would not, on being agitated in water, disintegrate or dissolve and pass through the sieve as a fine suspension, in the way that bottom mud usually does. It is thought that this physical peculiarity, which seems to obtain at this one sampling point only, is a result of the turbulence and water movement, which at this point are merely slackened by the eddy. The water does not come to rest, and the moderate movement which persists, while it permits the deposit of the larger and heavier portions of suspended matter, will meantime carry away the lighter, finely divided material. Moreover the prevalent turbulence, resulting in various temporary countercurrents at the sides of the main stream, would tend to roll this sediment over and over from time to time, thus encouraging the pelletlike formation.

This black, strong-smelling mud contained rather large numbers of tubificid worms, about 2,500 worms per liter, thus giving further evidence of its high content of organic matter. Egg capsules of these worms were present in small numbers, and the sewage fungi *Leptomitius* and *Sphærotilus*, probably detached from bottom stones, gave evidence of the prevalence of these growths on the floor of the stream.

In mid-May the grayish turbulent water gave off a moderate odor of sewage. Flocculent matter was floating as in early April but these

masses were composed of *Carchesium* and *Epistylis*. The sewage fungi of the previous month seem to have disappeared. Small amounts of the pollutional green alga *Stigeoclonium* were floating, as were also rather large numbers of small dead fish.

The margins showed abundant growth of *Carchesium*, and small quantities of *Stigeoclonium*, the latter having many diatoms attached. The marginal stones were almost free from any coating of blue-green alga. Thousands of small dead fish were observed stranded along the margins up and down stream as far as one could see.

Bottom sediment was black, coarsely granular as in May, and with tarry odor. One liter of this mud yielded 4,600 tubificid worms, a moderated number of egg capsules of the same, and small quantities of *Carchesium*.

The spring plankton averaged 798 units, as compared with the winter average of 448 units, a gain of 76 per cent. Index organisms showed a predominance of pollutional forms. The three spring months showed gradual increase in total plankton. See Table 19.

Predominant plankton organisms were the diatoms *Synedra*, *Asterionella*, *Fragilaria*, *Tabellaria*, with *Melosira* frequently present. An unidentified very minute blue-green filament was common. The principal green alga were *Pleurococcus* (practically always present), and *Closterium*, *Scenedesmus*, *Tetraspora*, and *Staurastrum* occasional. Unknown minute green cells were usually present. Flagellates were represented by *Trachelomonas*, *Euglena viridis*, *Phacus*, and *Cryptomonas*. Pollutional ciliates *Carchesium* and *Colpidium* were always present, *Epistylis* and *Vorticella* frequent, and an occasional *Paramacium* and *Codonella*. Rotifers, especially *Rotifer tardus*, were slightly more numerous than in winter samples.

TABLE No. 20.—Classification of plankton organisms

STATION 286, BRANDON BRIDGE, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										
	Diatoms	Blue-green alga	Green alga	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	Total
1921											
October.....	286	19	453			16	106	4			
November.....	173	39	430			9	130	1			
December.....	97	39	375	19		14	34	1		11	
1922											
January.....	101	19	113	80		13	64	11	46	3	
February.....	16	27	131	3	7	8	123	1			
March.....	361	39	179			11	130	3			34
April.....	97	65	443			66	58	5			37
May.....	447	19	318	3		36	160	9	3		39
June.....	40	54	243	5	1	34	112	4			36
July.....	43	19	345		1	49	78	3	26		33
August.....	46	60	217	4	7	70	93	3			4
Averages:											
Autumn.....	255	36	439			13	113	3		6	335
Winter.....	71	25	293		3	12	99	6	15	19	455
Spring.....	373	39	394	1		39	117	3	3	30	798
Summer.....	61	43	237	3	3	83	94	3	9	28	517

June, July, and August, 1922.—In June the grayish turbulent water had only a slight odor of sewage. Large amounts of *Carchesium* and *Epistylis* were floating, also a few dead fish. The banks showed a luxurious growth of *Arum*, flags, and weeds. Along the immediate margins were large amounts of the white *Carchesium* and the bright green *Stigeoclonium*, the two growths frequently clinging to the same support. Marginal stones contained a heavy growth of *Oscillatoria* and *Phormidium*, these mats containing many diatoms (*Navicula*) and rotifers (*Rotifer tardus*) and a few ciliates (*Paramoecium*). *Carchesium* and *Stigeoclonium* were abundant in the shallow by-pass.

Bottom sediments were coarsely granular as usual, black, and with stinking, tarry odor. One liter of mud yielded 850 tubificid worms, a few egg capsules, and the usual tufts of *Carchesium* scraped from bottom rocks.

In July conditions were essentially the same, water grayish, turbulent, with slight odor of sewage, large total amount of *Carchesium* and *Epistylis*, with some *Stigeoclonium*.

The final visit in late August found the water somewhat high, grayish, turbulent, and with slight sewage odor. Moderate amounts of *Carchesium* and *Epistylis* were floating, similar amounts were along margins, but were more abundant in the shallow by-pass. The pollutional *Stigeoclonium* attached along margins or floating in small masses, was moderate in amount and showed abundant growth of *Leptothrix parasitica* on its filaments, as did also many stalks of *Epistylis*. Blue-green algae were abundant, carpeting marginal stones and covering to some extent the stones in the shallow by-pass. *Epistylis* and *Sphaerotilus* grew in moderate amounts along margins, and a small quantity of *Ulothrix*, a green alga, was also found. An unknown coarse green alga, unbranched, lashlike, but with diameter gradually increasing from base to tip, was found here for the first time.

Bottom sediments were black, with strong tarry nauseous odor, and coarsely granular. One liter yielded over 5,500 tubificid worms and a large amount of *Carchesium*. *Epistylis*, *Leptomitia*, and *Sphaerotilus* were also present in smaller amounts. Very large numbers of *Rotifer tardus* were in this sediment also.

Plankton showed the usual predominance of pollutional forms and of oxygen producers. (See Tables 3 and 9.)

Predominating organisms in the summer plankton were *Synedra*, *Navicula*, and *Tabellaria* of the diatoms; *Pleurococcus*, *Scenedesmus*, *Actinastrum* and minute unknown cells represented the green algae. A minute green *Euglena*, *Chlamydomonas*, *Euglena viridis*, and *Trachelomonas* were the chief flagellates. Pollutional ciliates, especially *Carchesium*, *Epistylis*, *Colpidium*, and *Vorticella* were always present. The pollutional *Rotifer tardus*, though very abundant in mats of blue-

green algae and in the bottom sediments, was found in only six of the summer plankton samples. It was practically the only rotifer. Crustaceans and minute worms were present occasionally.

Summary.—The foregoing 11 months' record of visible conditions at this station, and of predominating forms of life along margins and on bottom, together with exhaustive data concerning the amount and kinds of plankton organisms found in weekly samples, constitute sufficient basis for the following conclusions:

(1) The rapid, turbulent water, the grayish color, and the moderate odor of sewage are the outstanding characteristics of this portion of the river. (Table 18.)

(2) The great abundance of *Carchesium* and *Epistylis*, attached in tufts along margins, abundant on the bottom, and small detached masses floating downstream, is the most noticeable feature relative to the larger forms of life. These growths are present throughout the year, but are less abundant in winter.

(3) Bottom sediments are characterized by a vile odor and by large numbers of such worms (the tubificids) as prefer an environment of heavy pollution. No clean-water organisms are present.

(4) Study of the index plankton shows predominance of such forms as are known to indicate pollution, the average for the year being 60 per cent pollution organisms and 40 per cent cleaner-water organisms. (Table 6, column 25.)

(5) The total plankton showed, throughout the year, a safe majority¹⁰ of oxygen producers. During only two months (January and February) did this content fall below 60 per cent. The average for the 11 months was 77 per cent oxygen producers and 23 per cent consumers. (Table 6, column 23.)

Discussion.—There is no question as to the sanitary status of the water in this section of the river. The heavy pollution with sewage is evident to the casual observer. It need only be pointed out here that for 11 months, elaborate examinations of prevailing plant and animal life, study of the nature and contents of bottom sediments, and study of the plankton as well, all these lines of evidence agree in the verdict that the water is grossly polluted. The larger forms of life in water and in bottom mud or attached to stones are those which are found only in the presence of heavy pollution. Meantime there is conspicuous absence of any of those organisms that are commonly found in water known to be relatively clean.

The plankton tells the same story, but with some limitations. These minute organisms, unattached, and carried passively by the movements of the water, are necessarily a record of the recent environment of the flowing water, a biological reflection of where the

¹⁰ After exclusion of those diatoms (often the major portion), which on careful examination were judged to be dead or in a dying condition.

water has been during the lifetime of the organism concerned. Thus a given point in a stream, if within reasonable distance below a tributary, will show in the plankton content those organisms that were common in the tributary and have been transferred to the main stream by the movement of the water. Thus it is that the plankton at Brandon Bridge contains many organisms, particularly the minute green alga, which were abundant in the Des Plaines River about 6 miles above this point. Many diatoms, obviously from Lake Michigan, are also present, for in point of time the lake is only two or three days distant. Many of the diatoms found were dead and empty.¹¹ These were excluded from our counts of active organisms, though they probably should be regarded as additional evidence of the unsuitable character of the water here for those diatoms that flourish in the clean water of Lake Michigan. Because of these recent environments of portions of this water in Lake Michigan and the Des Plaines River, respectively, many of the plankton organisms still alive in the water at this station (Brandon Bridge) are those from the cleaner waters mentioned. Sufficient time has not yet elapsed to kill off the more tolerant cleaner-water organisms from these waters. For the same reason such organisms as are characteristic of the heavy pollution obvious at this station have not yet developed to their usual large numbers, and therefore we find, in the plankton, an average of only 60 per cent of such organisms as indicate heavy pollution, and 40 per cent of those that indicate cleaner water. It would seem reasonable that, as further time elapses, and the sewage reaches the peak of its decomposition in consequence, the proportion of sewage-loving organisms will increase, and organisms requiring cleaner environment will decrease.

An appraisal and summary of the situation at Brandon Bridge would be incomplete and unfair without due recognition of two or three factors that give promise of better things for the polluted water. The first item of promise is the thorough mixing of the water, with whatever sewage or organic matter it may contain, as the stream passes through this turbulent section, including a 12-foot fall over the Jackson Street Dam. The current, countercurrents, and eddies compel a prolonged mixing that is thorough and complete, even to the very edges of the stream, in this 3-mile section where the slope averages $6\frac{1}{2}$ feet per mile. This effective mixing prepares the way for the successful attack of such chemical and biological agencies as may be available for the ultimate disposal of the harmful organic matter as such.

¹¹ Determined by careful examination, under one-sixth objective, of the majority of the diatoms in the counting cell containing 1 c. c. of the plankton catch. After the routine examination the cover glass was removed and the diatoms reexamined by lowering the high-power objective into the contents of cell until diatoms were in focus.

The second item, already noted to some extent, is the very large quantities of colonial ciliates attached in tufts and masses along the stream margins and practically carpeting the bottom. In addition to these, the same organisms are abundant in the plankton, either singly or in minute colonies. All of these are characteristic sewage organisms. They are not found in clean water. Whatever work they do is therefore concerned with the breaking down of sewage, in which they find abundant food, judging from their enormous numbers. Furthermore, the work performed by them in this portion of the river must necessarily, on account of these enormous numbers, be sufficient in amount to command at least the respectful attention of any person who desires all the facts relative to the natural purification process in a polluted stream.

This abundance of biological workmen to attack the organic matter is apparently ably seconded by a different class of organisms that are effective in a different way. Reference is made to the oxygen-producing organisms, minute green algae from the Des Plaines and diatoms from Lake Michigan. Such as were tabulated in our examinations seemed to have a normal content of chlorophyll and to be in fit condition for work. If these successfully survive the conditions of heavy pollution in this portion of the river, and are therefore present and equipped for service as soon as the flowing water shall have become sufficiently clear¹³ and fit for their activities farther downstream, then the water will be in immediate possession of a valuable ally in that the excess oxygen produced by these synthetic workmen will supplement that obtained from the air meantime, and will make possible even greater activity on the part of those oxygen-consuming organisms that wage war on the organic matter of the water.

As the water leaves this section, it might be described as a heavily polluted stream whose organic matter, of comparatively recent origin, is most thoroughly mixed with a large proportion of lake water, and with smaller amounts from the Des Plaines, the latter in particular supplying a heavy seeding of oxygen-producing organisms. The great numbers of pollution-loving organisms on margins and bottom, and of free-swimming organisms of similar liking in the plankton, give reasonable promise that the burden of sewage, though heavy, will be speedily and perhaps successfully attacked, and the many chlorophyll-bearing organisms present offer strong probability that reinforcements of dissolved oxygen will be available when needed.

¹³ The water is grayish in appearance, on account of the large amount of minute suspended matter. The turbidity in the 47 samples during the 11 months reached 50 or more only 11 times, all other turbidity readings being below 50. The average of all readings was 38. While such turbidity might check photosynthesis somewhat in the deeper water, it would apparently have little or no such effect at and near the surface, for the green filamentous pollutional alga *Stigeoclonium* grew quite plentifully in the shallow water of the by-pass.

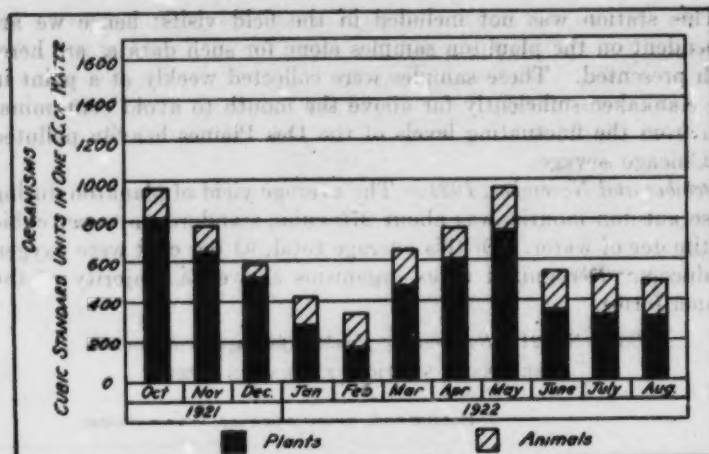


FIGURE 5.—Station 286. Monthly averages of weekly plankton catches expressed as plants and animals

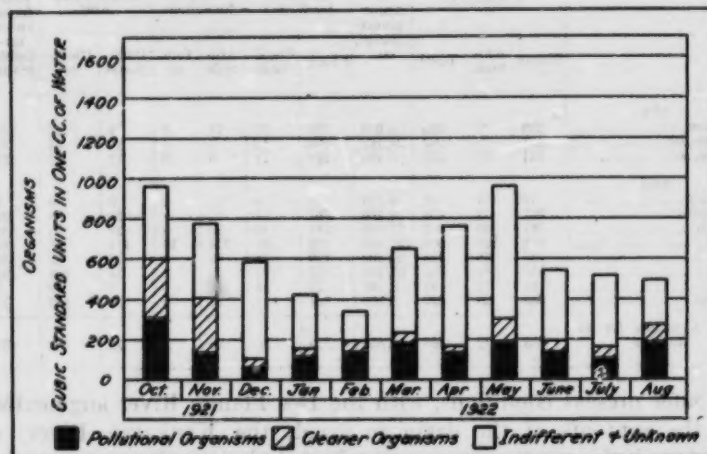


FIGURE 6.—Station 286. Monthly averages of weekly plankton catches expressed as pollutional, cleaner, and indifferent

THE KANKAKEE RIVER

The Kankakee River unites with the Des Plaines at a point about 14 miles below Brandon Bridge, and approximately 273 miles above the mouth of the Illinois River, this latter stream being formed by the union of the Des Plaines and the Kankakee.

Under the conditions obtaining during the 11 months covered by this study the Kankakee contributed an average of 34 per cent of the combined waters below the point of junction.

This station was not included in the field visits; hence we are dependent on the plankton samples alone for such data as are herewith presented. These samples were collected weekly at a point in the Kankakee sufficiently far above the mouth to avoid contamination from the fluctuating levels of the Des Plaines heavily polluted by Chicago sewage.

October and November, 1921.—The average yield of plankton during these autumn months was about 270 cubic standard units per cubic centimeter of water. Of this average total, 93 per cent were oxygen producers. Recognized index organisms showed a majority of the cleaner forms.

TABLE No. 21.—Summary of plankton findings for all months
AVERAGES AT STATION—KANKAKEE RIVER

Date	Plankton catch, cubic standard units in 1 c. c. of water										
	Total catch				Total organisms						
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutational	Cleaner	
1921											
October.....	233	40	282	5,600	233	26	24	0	19	36	237
November.....	234	23	257	28,800	228	15	8	6	16	44	196
December.....	244	26	270	9,100	244	22	5	0	13	16	241
1922											
January.....	75	11	86	9,100	75	0	11	0	0	0	96
February.....	367	71	438	24,100	367	51	21	0	24	66	248
March.....	581	46	627	27,900	581	10	36	0	21	63	554
April.....	610	368	978	125,400	594	54	314	16	114	25	838
May.....	337	76	413	20,200	329	24	52	8	42	68	304
June.....	635	81	716	14,200	533	73	10	3	18	234	305
July.....	81	14	95	9,500	77	4	10	4	0	12	83
August.....	364	28	392	8,300	364	8	20	0	10	165	217
Averages for 11 months.....	333	72	405	25,650	339	26	46	3	25	64	315

Under present conditions, with the Des Plaines River augmented by the contents of the drainage canal, the Kankakee River, a comparatively small stream, contributed during the two months mentioned about 23 per cent of the combined waters below the point of junction, thus serving to dilute somewhat, with its cleaner waters, the heavily polluted larger volume of water contributed by the Des Plaines River.

The light plankton yield of the Kankakee showed a normal¹³ variety of organisms. *Synedra*, *Navicula*, and *Melosira* were the chief diatoms. Blue-green algae were only occasionally present in

¹³ The persistent absence of a representative number of the natural groups of plankton organisms is an indication of some interference with natural stream conditions. The unnatural plankton content of the Monongahela River is an example. See Pub. II. Bulletin 131, pp. 25, 26 (or see Abstract No. 5, item 8, p. 11.)

small amount. The more abundant minute green algae were *Pleurococcus*, *Tetraspora*, *Polyedrium*, minute unknown cells, and *Staurastrum*. Flagellates were represented by *Cryptomonas* and *Phacus*, with occasional presence of very small amounts of *Euglena*, *Trachelomonas*, *Chlamydomonas*, and *Glenodinium*. The ciliates were found only in very small amounts, *Halteria*, *Vorticella*, and *Colpidium* each being present once only.

TABLE NO. 22.—Classification of plankton organisms
STATION KANKAKEE RIVER, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	
1921											
October.....	80	3	181			36	14			7	
November.....	65	26	137	6		15	3			6	
December.....	16		236			22				8	
1922											
January.....	7		66							11	
February.....	40		337			81				31	
March.....	88	84	459		2	19	11			23	
April.....	49	18	639	16		57	64			168	
May.....	33	3	289	8		30	26			18	
June.....	102	5	436	3		72	1	1		9	
July.....	12		65	4		6				8	
August.....	7	23	334		1	11	7			9	
Averages:											
Autumn.....	56	15	187	3		21	7			6	267
Winter.....	31		266			34				13	308
Spring.....	60	19	438	7	1	30	33	34	1	65	608
Summer.....	38	10	279	2		26	3			8	366

December, 1921, January, and February, 1922.—The winter collections averaged 265 standard units, with high content of oxygen-producing organisms and predominance of cleaner forms in the light content of index organisms.

There was less variety in this winter plankton than in the autumn catches. *Synedra* and *Navicula* were again present. These, with a few *Pleurosigma*, made up the diatom content. *Pleurococcus* and minute unknown cells made up the bulk of the microscopic algae, but *Staurastrum*, *Scenedesmus*, and *Closterium* were sparingly present. *Cryptomonas*, a minute *Euglena*, and *Trachelomonas*, of the flagellates, were occasionally found. Ciliates were practically absent. No rotifers were found, and only a single specimen of the crustacea—a nauplius form—occurred in one winter sample.

March, April, and May, 1922.—The advent of spring brought an increase in the plankton, the average winter total of 265 units being succeeded by a spring average of 670 units, over two and one-half times the winter yield. The oxygen producers constituted 79 per cent of the total catch. The active index organisms showed pollutional and cleaner forms on a 50-50 basis essentially.

Of the diatoms, *Synedra* and *Navicula* were the most common. *Pleurococcus* and minute unknown cells were present in practically every sample, and *Tetraspora*, *Ankistrodesmus*, *Scenedesmus*, *Closterium*, and *Staurastrum* constituted the principal remaining members of the minute green alga contingent. Flagellates were not abundant, *Cryptomonas*, *Trachelomonas*, and a minute *Euglena* being about the only ones present, and these in only three or four collections. The pollutional ciliates *Colpidium* and *Carchesium* were present in 6 of the 13 collections, and two other ciliates of like sanitary status, *Vorticella* and *Epistylis*, were in 3 collections each. There was occasional occurrence of *Halteria*, *Loxophyllum*, and *Tintinnus*. The rotifers *Brachionus pala*, *B. mullerii*, and *Anurxa cochlearis* were found in two collections each, and a single crustacean in one sample.

June, July, and August, 1922.—The summer collections yielded an average total of 368 units, with high percentage of oxygen-producing forms, and a heavy predominance of the cleaner forms in the index organisms.

Predominating organisms in the summer plankton were *Synedra*, *Navicula*, and *Melosira*, of the diatoms, small fragments of *Oscillatoria*, and occasional specimens of *Merismopedia* of the blue-green alga. *Pleurococcus*, *Tetraspora*, *Scenedesmus*, and *Ankistrodesmus*, of the minute green alga, together with the ever-present unknown green cells. Also *Polyedrium*, *Celastrum*, and *Dictyosphaerium* appeared occasionally in the collections. Flagellates were represented rather sparingly by *Trachelomonas*, *Cryptomonas*, *Phacus*, *Euglena*, and *Chlamydomonas*. The pollutional ciliate *Carchesium* appeared in two samples in small amount, and *Vorticella* in one sample.

Summary.—The preceding record of the plankton of the Kankakee for eleven months shows the following outstanding features:

1. Plankton yield is comparatively light. Inspection of Table 5 will show that the average yield per month (using this as a convenient basis of comparison) is smaller than that of any other station. It is less than two-thirds of the yield at station 292, where the plankton has not reached its full content on account of the recent origin of the sewage. The average yield of the Des Plaines at Sixteenth Street, Lockport, is nearly four times that of the Kankakee, and the yield of the Spoon River at Havana is nearly three times as much.
2. The oxygen-producing organisms average, throughout the 11 months, 88 per cent of the total plankton. (Table 8.)
3. Organisms indicating the presence of pollution appear in the averages of 9 of the 11 months, and for the entire 11 months period these organisms averaged 28 per cent of the active index organisms. (Table 6, column 25.)

4. The seasonal changes in relative quantity of total plankton are quite different in the Kankakee as compared to the Des Plaines River and to the Spoon River. Inspection of the seasonal averages given in Table 3 shows, in the Des Plaines and the Spoon, a plankton content in summer twice that of the spring yield, diminishing considerably in autumn and yielding relatively smallest values in winter. The Kankakee, meantime, shows a summer content about half that of the spring, with only slight change with the advent of autumn, and of winter. This is an unusual state of affairs, with no explanation available as to why the Kankakee should thus differ from the average stream in its seasonal values.

It thus seems that the advent of the Kankakee will furnish some dilution to the polluted larger stream, not only because of the smaller yield of total plankton, but also on account of the smaller proportion of those organisms that indicate presence of pollution.

STATION 263. MORRIS

The turbulence characteristic of the water at Brandon Bridge continues, but with perceptible decrease for several miles downstream. The steep gradient of $6\frac{1}{4}$ feet per mile ends a mile or two below Brandon Bridge, and a gradient averaging about 1.2 feet per mile then prevails to Morris (23 miles below Brandon Bridge) and beyond, with temporary decrease of effective gradient and of current as a result of the dam at Marseilles, 17 miles below Morris.

At Morris the water is still grayish in color, due to large amounts of minute suspended matter. Small floatage includes fragments of the attached colonial organisms that are so plentiful at Joliet. The larger floatage consists mainly of masses of material, dark or grayish in color, that apparently originate from some sludge bar, or from the bottom of the stream in an occasional small area where the water is relatively quiet, and thus permits the accumulation of deposits which, on decomposing, will give off from time to time a mass of dark, sludgelike material. These masses, buoyed up for a time by gases, float downstream, presently breaking up and the fragments are scattered along the bottom. The water at Morris had a noticeable sewage odor.

Ten miles above Morris the relatively unpolluted Kankakee River joins the Des Plaines, thus forming the Illinois River proper.

Plankton samples were taken at Morris weekly at midstream by means of lowering the sampler from the bridge. No mud samples were obtained at this station, hence all our data will be concerned with the plankton samples only.

TABLE No. 23.—Summary of plankton findings for all months

AVERAGES AT STATION 203

Date	Plankton catch, cubic standard units in 1 c. of water										
	Total catch				Total organisms						
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutational	Cleaner	
1921											
October.....	1,200	999	1,999	12,500	1,190	30	999	10	201	942	656
November.....	870	897	1,467	21,900	636	6	891	34	556	340	571
December.....	344	268	632	21,700	344	0	268	0	262	30	300
1922											
January.....	203	131	434	13,600	282	3	148	23	128	38	389
February.....	241	150	491	7,800	286	3	147	46	173	35	391
March.....	657	473	1,160	26,000	579	62	411	47	433	41	666
April.....	989	323	1,222	95,700	865	3	330	34	192	82	998
May.....	584	297	881	12,600	584	48	249	0	250	101	510
June.....	449	108	557	15,100	427	8	90	22	154	108	300
July.....	327	165	492	10,100	327	43	122	0	129	107	235
August.....	355	172	527	9,700	340	65	107	15	149	65	313
Averages for 11 months.....	570	312	881	22,520	549	25	267	20	276	145	460

October and November, 1921.—The autumn plankton yielded the high average total of about 1,650 cubic standard units. Oxygen producers made up 61 per cent of this total catch. Active index organisms showed a slight majority of the pollutational forms. (See Table 6, columns 6, 7, and 9.)

The leading organisms in the plankton were as follows: The diatoms *Tabellaria fenestrata* and *Melosira* in a large majority of the samples, and *Navicula*, *Synedra*, and *Fragilaria* in 4 or 5 of the 9 autumn samples. Minute fragments of *Oscillatoria* or other blue-green algæ were frequently present. Minute green algæ were *Pleurococcus*, *Scenedesmus*, and unknown green cells in all samples, with *Pediastrum*, *Tetraspora*, *Closterium*, and *Botryococcus* occasionally present. Flagellates were few in number, *Cryptomonas* being found in two samples, and *Chlamydomonas*, *Euglena*, and *Anthophysa* in one sample each. The pollutational ciliates *Carchesium*, *Epistylis*, *Vorticella*, and *Colpidium* were rather abundant in nearly every sample, and *Paramacium*, another pollutational ciliate, appeared in four samples. The pollutational rotifer *R. tardus* also was in most of the collections. *Cyclops* and *naupleii* appeared in two samples, and nematode worms in two.

It will be noted in Table 6 that the average yield of nearly 1,700 units is a great increase (almost double) over the autumn average, 857, at Brandon Bridge, only 24 miles above this point. This is in all probability due chiefly to the greater and increasing degree of decomposition attained by the sewage. While only a few hours (about 10) have elapsed since the stream was passing Brandon Bridge,

the conditions meantime have been such as to favor rapid change both chemical and biological. Reference is made to the continuous mixing, turbulence, and turnover experienced by the water, during which all portions of the mixed sewage and water must necessarily come in contact with the air at the surface perhaps many times. The treatment is an approach to that involved in the "activated sludge" procedure with sewage. This being true, we may expect quick results in such chemical and biological conditions as are affected by the vigorous treatment. It would seem therefore that all contained organic matter is thoroughly mixed and put in favorable condition for effective bacterial action; that resulting heavy bacterial growth will provide necessary food for increased numbers of such organisms, particularly ciliates, as feed mainly on the bacteria; and that the water so continuously re-aerated by turbulence and overturn will speedily become habitable for an increasing variety of organisms, including those containing chlorophyll, which will, in turn, add more oxygen to the water by their own photosynthetic activity and thus encourage the conditions required for further effective bacterial action.

Tables 20 and 24 present data from these two stations summarized from the weekly plankton counts. Study of this record for October and November shows that while diatoms, blue-green algae, and green algae all increased at Morris by substantial percentages, yet in no other large group is such an increase shown as that exhibited by the ciliates, these having increased nearly fourfold and making up about 32 per cent of the total yield. It is obvious that the food supply of these ciliates (chiefly bacteria) must have been similarly abundant, and it is further obvious that the bacterial content of the water must have been materially reduced on account of the continuous inroads upon them by the fast-multiplying ciliate population.

TABLE No. 24.—Classification of plankton organisms
STATION 263 (MORRIS), MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										
	Dia- toms	Blue- green algæ	Green algæ	Fungi	Rhizo- pods	Flag- ellates	Cili- ates	Roti- fers	Cru- stacea	Spores, etc.	Total
1921											
October.....	445	47	667	10		50	527	34	10		
November.....	429	30	278	34		6	518	22			
December.....	125	3	216				264	6			
1922											
January.....	66	41	173	23		9	92		41		
February.....	50	28	203	46		13	125	3			
March.....	106	43	430	47		62	231	10		70	
April.....	174	16	679	24		120	110	1		162	
May.....	137	57	371			48	232	3		15	
June.....	87	109	230	22	4	8	74	20		3	
July.....	125	15	199			43	90	1		31	
August.....	46	73	221	15		60	83	5	11	4	
Averages:											
Autumn.....	496	37	515	23	13	26	522	27	5	40	1,633
Winter.....	61	31	197	23	6	6	100	3	14	10	335
Spring.....	136	26	487	26		75	232	5		63	1,063
Summer.....	82	66	214	13	2	43	85	5	4	9	336

December, 1921, January and February, 1922.—The plankton yield during the winter averaged 525 cubic standard units. The index organisms showed a heavy preponderance of the pollutional forms.

Organisms making up this winter plankton were the diatoms *Asterionella*, *Tabellaria fenestrata*, and *Synedra*, with *Navicula* and *Melosira* occasionally present; occasional fragments of blue-green algae were present. The minute green algae were *Pleurococcus*, *Botryococcus*, *Staurastrum*, and minute unidentified cells. Fungus hyphae and *Sphaerotilus* were occasionally found. Flagellates were all but absent. Pollutional ciliates were in nearly all samples, and were moderately abundant, the chief ones being *Carchesium*, *Epistylis*, *Colpidium*, and *Vorticella*, with *Paramacium* occasional. *Rotifer tardus* appeared in 4 of the 12 samples, and *Anurxa cochlearis* in 1 sample. An occasional *Cyclops* and nematode worm completed the list of winter organisms.

Although all plankton values are low in winter as a rule, due to the general slowing down of activities on account of low temperatures, yet the group ¹⁴ totals of the winter plankton, summarized from the weekly plankton counts, tends to show pretty much the same direction of change as does the autumn group summaries from the stations at Morris (station 263) and at Brandon Bridge. Group summaries recorded in Tables Nos. 14 and 16 show that while there is slight increase at Morris in diatoms, blue greens, and even slight decrease in green algae, there is nevertheless a very marked increase in pollutional ciliates, the total of these being twice as great at Morris as they are at Brandon Bridge.

March, April, and May, 1922.—The total plankton in the weekly samples during the three spring months averaged 1,064 cubic standard units, twice the average winter yield. Index organisms showed a decided majority of pollutional forms, as shown in Table 23.

Specific organisms making up the spring plankton were the diatoms *Synedra*, *Asterionella*, and *Navicula*, with a small amount of *Melosira* and *Tabellaria*. Blue greens were represented by occasional fragments. The green algae consisted chiefly of *Pleurococcus*, *Ankistrodesmus*, *Tetraspora*, and minute unknown cells. A few flagellates, mainly *Euglena* and *Phacus*, appeared in less than half the samples. Pollutional ciliates were again the dominating animal form, being exceeded only by the green algae in quantity. *Vorticella*, *Carchesium*, *Colpidium*, and *Epistylis* were continuously present, with an occasional *Paramacium*, or *Lionotus*. *Rotifer tardus* was found in 3 of the 12 samples.

Again we find, on summarizing the groups of organisms from the weekly counts at Brandon Bridge and Morris, respectively, that the

¹⁴ The several "groups" or families (diatoms, green algae, ciliates, etc.) that make up the average natural plankton content. (See Table 16.)

most noticeable difference between the two stations is the substantial increase in the pollutional ciliates, these having doubled in quantity in the samples taken at Morris. The minute green algae also have increased by 60 per cent over the Brandon Bridge figures, but the living diatoms¹² have decreased by more than half.

June, July, and August, 1922.—Summer plankton yielded an average total of 525 units, the same as the winter average (525 units) in quantity and about half the spring average of 1,064 units. See Table 23.

These summer plankton values are unexpectedly low. There is nothing of the usual increase over the winter yield which commonly is a feature of plankton growth, as may be noted by a study of Tables 20 and 24. Moreover, it will be noted that, though there has been material increase of the total plankton yield of autumn, of winter, and of spring, as the water progressed from Brandon Bridge to Morris, this summer plankton at the latter station does not show the expected amount of increase, the actual average yield being the same as the yield at Brandon Bridge. Investigation of the possible source of this disturbance of orderly data—that is, the relative volume of flow and the relative plankton content of the Kankakee River which unites with the Des Plaines about 10 miles above Morris—fails to reveal any adequate cause for the apparent failure of the summer plankton at Morris to measure up to the expected quantity. The normal increase and growth of organisms seems to have been checked, for some reason not apparent.

Predominating organisms in this summer plankton were as follows: The diatoms *Tabellaria fenestrata*, *Synedra*, and *Navicula* in a majority of the 13 samples, and *Fragilaria* less often. Fragments of a minute blue-green alga, unidentified, and also of *Oscillatoria*, were commonly present. Green algae predominating were *Pleurococcus*, *Tetraspora*, *Scenedesmus*, and minute cells in a large majority of the samples, *Ankistrodesmus*, *Celastrum*, and *Actinastrum* of frequent occurrence, and *Pediastrum* occasional. The pollutional fungi *Sphaerotilus* and *Beggiatoa* were in five and three samples, respectively. The flagellates *Euglena viridis* and *Chlamydomonas* were in about half the samples, with occasional appearance of *Phacus* and *Trachelomonas*. The distinctly pollutional ciliates *Carchesium*, *Vorticella*, and *Epistylis* were in practically every sample. *Colpidium* was in five samples. *Paramacium* and *Codonella* appeared in one and two samples, respectively. *Rotifer tardus*, in seven samples, was the only rotifer found except a single specimen of *Polyarthra* in one sample. Crustacea were sparingly present in two samples, and nematode worms in a like number.

¹² Of a total of 4,388 units of diatoms in the weekly spring samples at this station, 2,500 units, or almost 60 per cent, were adjudged dead or dying (see p. 91) and are not included in the data given above.

The list of organisms is very similar to the spring list. Summarizing the main groups (see Table 24) shows heavy reduction from the group summary of the spring samples in diatoms, green alga, and ciliates, and about equal values or slight increase over spring data in blue-green alga, flagellates, and rotifers. In a comparison with the group summary in Table 20 of the counts at Brandon Bridge (24 miles above) for these same summer months, it is found that diatoms, blue-green alga, and rotifers show substantial increase, but green alga and ciliates show decrease. This latter fact, decrease of the ciliates, is unexpected, in view of the fact that group summaries of autumn, winter, and spring, already noted, have shown heavy in-

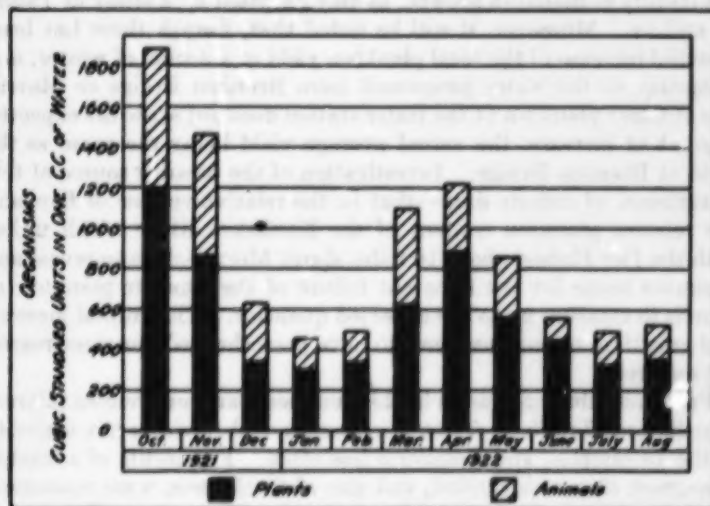


FIGURE 7.—Station 283. Monthly averages of weekly plankton catches expressed as plants and animals

crease of these organisms at Morris, apparently due to the greater degree of decomposition of the sewage and the increased food supplies, chiefly bacteria, thereby made available to these ciliates.

As already noted, the entire summer plankton at Morris is scant in amount and does not show the usual increase over winter yields that we expect in a normal stream. But this general paucity of the summer plankton as a whole does not seem sufficient explanation for the actual decrease of those pollutional organisms that have, for the three preceding seasons, shown the consistent growth and multiplication that would seem inevitable under the apparently favorable conditions of environment and abundant food as the decomposing sewage in the water progresses from Brandon Bridge to Morris.

Summary.—Notwithstanding the above apparent discrepancy, the unsatisfactory situation at Morris is explicable as seen in a review of the data for the entire eleven months. A summary of this situation is presented in the seasonal averages as given in Tables 20 and 24. It will be noted that, with a few exceptions, (1) there is slight increase at Morris over Brandon Bridge figures, in each group of organisms at all seasons. The most noticeable exceptions are seen in the green algae in winter and in summer, the diatoms in spring, and the ciliates in summer. (2) The totals of all groups—that is, the total plankton—show in every season an increase at Morris. The yield is practically doubled in the autumn, increased by 15 per cent in win-

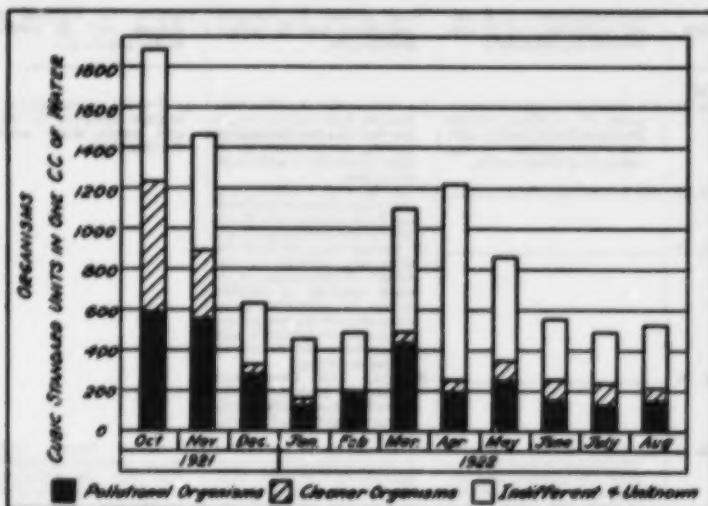


FIGURE 3.—Station 251. Monthly averages of weekly plankton catches expressed as pollutant, cleaner, and indifferent

ter, by 33 per cent in spring, but by only a scant 2 per cent in summer. (3) For the year as a whole the plankton yield at Morris shows an increase over that at Brandon Bridge of about 43 per cent. (4) More significant, however, is the fact that, of the three numerically important groups of organisms (diatoms, green algae, and ciliates), the year's totals show at Morris an increase of 147 per cent in the ciliates as compared with 13 per cent increase in the diatoms and 20 per cent in the green algae.

STATION 227. LA SALLE

The river at this point has lost much of the turbulence that characterizes the Joliet section, the gradient being only a little more than 1 foot per mile, instead of 6 feet per mile as in the turbulent

section mentioned. The current of nearly 3 miles per hour is still sufficient to prevent any extensive deposit of suspended matter except in some by-pass or other portion of the channel that is somewhat protected.

The sampling point was just above the mouth of the Vermilion River and 3 or 4 miles above the town of La Salle. The trip from La Salle by sampling boat to this point afforded ample opportunity to observe a representative portion of this section of the river.

TABLE NO. 25.—Bottom conditions, water surface, and stream margins

STATION 27 (LA SALLE)

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growth, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921			
June 25	(1) Black, soft, with offensive odor; (2) tubificid worms from one liter of mud, 2, 216; moderate number of egg capsules of these worms.	(1) Sewage odor; bubbles from bottom; brisk current; water grayish; (2) abundant sewage masses, up to washtub in size; <i>Carothium</i> and trash abundant.	(1) Wooded earth banks so shallow margin; (2) weeds and weeds; small amount floating algae.
June 30	No bottom sample.	<i>Epistylis</i> and <i>Rotifers</i> very abundant on strands of floating Potamogeton; few Tubificid worms in floating trash.	
Aug. 17		(1) Sewage odor; (2) <i>Epistylis</i> abundant, growing on detached Potamogeton; moderate number of <i>Rotifer</i> turds in sediment; moderate amount <i>Stigeodonta</i> ; fragments of <i>Spilogyna</i> and <i>Chydophora</i> ; few <i>Amphium</i> pupae in drift.	
Aug. 31		<i>Epistylis</i> and <i>Carothium</i> abundant, growing on detached Potamogeton; <i>Rotifer</i> turds abundant in sediment.	
Sept. 3	(1) Black, spongy, and with vile odor; fine detritus abundant; (2) tubificid and oligochaete worms in one liter of mud, 28; these worms were longer than usual, with some in two; egg capsules numerous.	(1) Sewage odor; bubbles from bottom; brisk current; water grayish; (2) Offy foam, bubbles, small amount debris, and minute, grayish flocculences.	(1) Earthy banks; shallow water, bubbles on bottom of east side; (2) <i>Oscillatoria</i> , <i>Spilogyna</i> , and <i>Tubificidae</i> moderately abundant in shallow strip; many <i>Rotifer</i> turds in sediment of <i>Oscillatoria</i> ; a few <i>Notonecta</i> observed.
Sept. 14		<i>Epistylis</i> and <i>Carothium</i> colonies attached to floating Potamogeton and culms; sediment contained <i>Rotifers</i> , nematodes, and tufts of <i>Stigeodonta</i> and <i>Spilogyna</i> .	
Sept. 20		<i>Chydophora</i> calanula (young) attached to floating culms.	

At the time of our first visit (latter June, 1921) floating material was abundant, chiefly gray-black masses in sizes varying from that of a walnut to that of a washtub. These masses readily broke up when disturbed by an oar, and much of the material would sink. The mass as a whole was distinctly granular and somewhat flocculent in nature, though it contained moderate numbers of tubificid worms and some *Epistylis*, etc. Besides these masses, there were small amounts

of blue-green algae floating, occasional tufts of the pollutional green alga *Stigeoclonium*, moderate amounts of fruit parings, small debris, and an occasional fragment of detached water plant, such as *Elodea* or *Potamogeton*. These usually had a heavy growth of *Carchesium* and *Epistylis* covering much of their surface. Very minute particles of suspended matter were very abundant, and imparted to the stream as a whole a grayish color. Bubbles were floating, and in many places were arising in large numbers from the bottom, indicating that septic action was in operation in such sediments as were not carried out by the current. There was a distinct sewage odor.

June, July, and August, 1921.—A bar or deposit of mud was found below the highway bridge (and about 3 miles below the sampling point) where, on the east side of the channel, the river widened out somewhat and the force of the current was much diminished. This mud was black, soft, full of gas, and had an offensive odor. One liter yielded over 2,200 tubificid worms. These were evidently in favorable environment, for they were multiplying, about 200 egg capsules being found with the worms.

During August further samples of floating weeds were collected and examined. The weeds were usually detached portions of *Potamogeton*. Small masses of *Stigeoclonium* were commonly present also, with occasional occurrence of *Cladophora* and *Spirogyra* in small amounts. Many of these algae and plant fragments, probably from some tributary or even from the Des Plaines, showed the character of the environment, in which they were now floating, by the actively-growing *Carchesium* and *Epistylis* almost invariably found attached to them. In the minute sediment still clinging to these plants were many *Rotifer tardus*.

Regular plankton collections were begun in July, and the summer averages are based on the collections of July and August. The summer average total plankton yield was 842 cubic standard units. The index organisms found were about equally divided as to pollutional and cleaner forms.

Organisms predominating in the summer plankton were *Tabellaria fenestrata*, *Synedra*, and *Navicula* of the diatoms, fragments of the blue-green alga *Oscillatoria*; *Scenedesmus*, *Tetraspora*, *Pleurococcus*, and *Calanistrum* of the green algae, together with minute unknown cells; *Beggiatoa* and *Sphaerotilus* of the fungi, the flagellate *Euglena viridis*, the pollutional ciliates *Carchesium*, *Epistylis*, and *Vorticella*, also *R. tardus* and *R. actinurus* of the rotifers.

September, October, and November, 1921.—Early September showed about the same conditions as those noted in June—the brisk current, small debris and plant fragments floating, these containing growths of *Epistylis* and adhering sediment containing rotifers. Septic bubbling was still in progress. Large amounts of minute flocculent matter

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was in suspension, giving a grayish color to the water as a whole. Small amounts of the green alga *Spirogyra* and of the blue-green *Oscillatoria* were found growing near the shore line on the east side. Many rotifers (chiefly *R. tardus*) were in and on these algæ.

Mud samples obtained as before below the highway bridge were black, very soft and spongy, and had a vile, repellent odor. Large amounts of minute, chafflike detritus were in this mud, which also yielded 220 tubificid worms, and numerous egg capsules of the same; to the liter of mud. No clean-water organisms were found. A few *Notonecta* were seen near the margin, but these insects come to the surface for air, and are to a great extent indifferent to the lack of dissolved oxygen in the water.

The plankton yield for the autumn months showed an average total of 1,000 units, of which 518 units were active index organisms. Again the division, as to pollutional and cleaner forms, was about half and half. (See Table 26.)

TABLE NO. 26.—Summary of plankton findings for each month

AVERAGES AT STATION 227 (LA SALLE)

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms							
	Organisms			Amor- phous matter, etc.	Oxygen producers		Oxygen consumers		Index organ- isms		Indif- ferent and of un- known status	
	Plants	Anim- als	Total		Plants	Flagel- lates	Anim- als	Fun- gi	Pollu- tional	Clean- er		
1921												
July.....	791	237	962	8,300	656	104	132	75	250	330	388	
August.....	555	169	713	7,700	548	26	133	9	211	179	328	
September.....	1,000	183	1,183	11,300	937	52	131	14	220	270	692	
October.....	680	442	1,122	13,800	680	43	399	0	378	361	383	
November.....	580	144	724	20,300	580	25	119	0	134	192	400	
December.....	443	456	899	22,800	440	30	426	3	346	75	475	
1922												
January.....	390	91	481	17,800	376	6	23	14	161	47	271	
February.....	379	313	692	34,700	376	0	113	4	309	80	304	
March.....	482	174	656	83,500	469	22	152	13	172	32	452	
April.....	402	36	438	122,500	402	0	28	0	8	35	394	
May.....	556	348	904	33,300	553	0	309	3	332	62	510	
June.....	566	126	692	12,700	566	8	118	0	114	166	411	
July.....	573	198	771	8,300	568	78	120	5	196	213	363	
August.....	435	138	573	6,000	480	10	127	6	119	192	361	
Averages for 11 months.....	511	227	738	34,230	504	26	200	8	213	137	388	

Predominating organisms in the plankton were *Tabellaria fenestrata*, *Melosira*, *Navicula*, and *Synedra* in nearly all the 13 samples, and *Tabellaria flocculosa*, *Asterionella*, and *Fragilaria* in five or six samples. Fragments of blue-green algæ were frequent. Leading green algæ were *Pleurococcus*, *Scenedesmus*, *Tetraspora*, *Pediastrum*, and *Botryococcus*. The fungi were represented by *Beggiatoa* in

nearly half the samples, and the flagellates by *Euglena viridis*, *Anthophysa*, *Phacus*, and *Chlamydomonas*. The usual ciliates *Carchesium*, *Epistylis*, and *Vorticella* appeared in most of the samples, along with *Colpidium* which had been very infrequent in the summer samples. Other ciliates present occasionally were *Paramacium*, *Tintinnus*, and *Lionotus*. The common *Rotifer tardus* was found in more than half the samples. *Cyclops*, of the crustacea, appeared in one sample.

TABLE NO. 27.—Classification of plankton organisms
STATION 227 (LA SALLE) MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1921											
July.....	154	85	417	75	5	104	59	43		20	-----
August.....	90	114	346	9		26	93	30		10	-----
September.....	365	106	516	14	2	93	59	26		4	-----
October.....	271		409			50	283	13	34	44	-----
November.....	234	11	346		1	30	105	5		3	-----
December.....	70	13	352	3	1	41	329			85	-----
1922											
January.....	150	58	169	14	3	8	74	4		3	-----
February.....	152	10	214	4	3	5	268	8		10	-----
March.....	42	31	376		2	22	127			22	-----
April.....	142		360			8	9	2		18	-----
May.....	223	21	312	3		56	270			28	-----
June.....	68	113	385			8	63	2		32	-----
July.....	102	118	348	4		78	92	5		23	-----
August.....	21	69	340	6		11	97	13		15	-----
Averages:											
Summer.....	122	99	381	42	3	66	78	37		18	942
Autumn.....	280	43	425	5	1	61	139	14	9	14	1,090
Winter.....	124	27	245	7	3	18	239	4		32	660
Spring.....	136	18	321	6	1	26	135			21	668
Summer.....	64	101	360	3		30	90	6		25	679

December, 1921, January, and February, 1922.—No further field trips were made to this section of the river until the summer of 1922; hence the following statements of winter and spring conditions are dependent on data derived from the weekly plankton collections.

The winter plankton showed an average total yield of 690 units, of which 339 units were active index organisms, 80 per cent pollutional and 20 per cent cleaner-water forms.

The list of winter organisms comprised the diatoms *Asterionella*, *Tabellaria fenestrata*, *Synedra*, and *Melosira* in most of the samples, with *Navicula*, *Fragilaria*, and *Pleurosigma* in a few. Blue-green algae fragments were occasionally present. Predominating green algae were *Pleurococcus*, and minute unknown cells, also *Scenedesmus*, *Tetraspora*, *Dictyosphaerium*, and *Raphidium* in several samples. The fungus *Sphaerotilus* appeared in three collections, and the flagellates *Euglena* and *Anthophysa* in a similar number. The usual quota of pollutional ciliates *Carchesium*, *Epistylis*, and *Colpidium* was in practically every sample, with *Vorticella* and *Paramacium* fre-

quently present also. Of the rotifers, *R. tardus* was found in four collections and *Anurax cochlearis* in two.

March, April, and May, 1922.—The spring yield of plankton showed a slight decrease over the winter yield. The latter (average total) was 690 units. The spring average total was 666 units. Active index organisms averaged about 214 units, 80 per cent of these being indicators of heavy pollution.

Predominating diatoms were *Synedra*, *Asterionella*, and *Fragilaria*. Blue-green algae were only occasionally present. Green algae were *Pleurococcus*, *Raphidium*, *Clostridium*, and *Scenedesmus*. Flagellates were few, *Trachelomonas*, *Euglena*, and *Chlamydomonas* being found in three samples. Ciliates were predominant as usual, *Carchesium*, *Colpidium*, and *Epistylis* appearing in practically all samples, with *Vorticella* and *Codonella* in a few. Rotifers and Crustacea were apparently absent.

June, July, and August, 1922.—The field trip, in late July, concerned the river as seen near Starved Rock, 2 or 3 miles above the La Salle sampling point. The conditions here are essentially identical with those at La Salle so far as the stream is concerned. The left bank, however, presents a striking peculiarity in the precipitous, lofty walls of rock (chief of which is Starved Rock) which line the east or south edge of the water for nearly a mile.

Small amounts of sludgelike material in grayish masses were floating. Margins showed growth of blue-green algae in moderate amounts. A moderate sewage odor was noticeable. Septic action was apparently absent, for bubbling was not noticed. The evident reason for this is the fact that the bottom above and below Starved Rock consists almost wholly of sand. Eight hauls at different points with the mud scoop secured only occasional traces of mud in the sand. The water surface was smooth, and only the surface floatage showed the brisk current of about 2 miles per hour.

The water was the usual grayish color, due to the large amount of minute suspended matter. Small amounts of *Carchesium* and *Epistylis* were floating in small, detached tufts, and occasional floating strands of detached waterweed contained an abundant growth of these pollutional ciliates.

The plankton yield of the summer months averaged a total of 679 units. Of this total, 333 units were active index organisms, these being 43 per cent and 57 per cent pollutional and cleaner water forms, respectively.

Synedra was the most abundant diatom, with *Tabellaria fenestrata*, *Navicula*, *Fragilaria*, *Melosira*, and *Asterionella* commonly present in varying quantities. Minute fragments of blue-green algae, chiefly *Oscillatoria*, were moderately abundant. The green algae were *Pleurococcus*, *Scenedesmus*, and *Tetraspora*, in practically all the samples,

and *Coelastrum*, *Raphidium*, *Actinastrum*, *Closterium*, and *Staurastrum* in about half the collections. Of the fungi, *Sphaerotilus* and *Beggiatoa* were occasionally present. Flagellates were not numerous, *Euglena viridis*, *Phacus*, and *Cryptomonas* being present only occasionally. As usual, the pollutional ciliates held first place as to general prominence, *Epistylis* being present in 9 of the 13 summer samples, *Carchesium* and *Vorticella* in 8 each, and *Colpidium* in 5, while the cleaner-water ciliate *Codonella* was found but once. The rotifer population likewise reflected the prevalence of organic matter, the familiar sewage form *R. tardus* occurring in seven samples and being practically the only rotifer present. Crustacea were not found at all.

Summary.—Summarizing the conditions at La Salle, as shown by three field trips, a few bottom and floatage samples, and weekly plankton collections for over a year, we note:

(1) Convincing evidence of heavy pollution is apparent to the casual observer, as at Brandon Bridge, 60 miles above. The odor of sewage, the gray-black masses of floating material, the various other kinds of floatage, the unnatural grayish color of the stream as a whole, and the bubbles arising from the bottom—all these impress the observer as indications of the prevailing unclean environment and of the utter unfitness of this water for many of those uses to which the average unpolluted stream is wont to be put by mankind, such as water supply, boating, bathing, and utilizing the banks as residence sites. These are impossible and unthinkable. (Table 25.)

(2) The one function of the river at this place is that of sewage removal. It is a thoroughfare for Chicago's sewage, and incidentally for that of small towns in the Illinois Valley, including La Salle.

(3) Character of the plankton is practically identical with that at Morris, 36 miles above. (See Tables 24 and 27.) This similarity includes: (a) Class of predominating animal organisms—ciliates. (b) General make-up of the plankton as a whole. Essentially the same organisms, and the same groups are predominant.

(4) Predominating character of the plankton is not only an indication of the presence of much organic matter, but, as at Brandon Bridge it is likewise assurance that the proper biological workmen are on hand, in reasonable force, to dispose of this organic matter. The approximate 50-50 status of the pollutional and the cleaner forms is to be noted, as shown by the seasonal averages of summer and autumn, 1921 and again in the summer of 1922. During the remaining seasons (winter, 1921-22, and spring, 1922) the status of the pollutional and the cleaner forms was practically the same as at Morris, 36 miles above. (See Table 3. See also Table 4, average for all months.)

(5) In like manner, the prevailing large proportion of oxygen-producing organisms (averaging 77 per cent of the total plankton content for the entire 14 months) is reasonable promise of substantial support for the aerobic bacteria in their work of reducing the organic matter.

(6) The average total plankton production for the four seasons at La Salle is 79 per cent of the production at Morris for the same period. (See Table 6, columns 6, 10, 14, and 18.) This may be due to the gradual decrease of the pollution organisms while meantime the cleaner-water organisms have not yet had sufficient time nor suitable environment to multiply to advantage.

(7) There seems to be some inhibiting factor affecting the summer plankton at this station, as was noted at Morris, for in both cases the summer yield is only slightly different from the winter yield in amount. The cause for this is at present unknown.

STATION 196. HENRY

After the river had been observed and studied for several months it seemed probable, from consideration of bacteriological data and certain biological findings,¹⁸ that the 65-mile stretch below La Salle and above Peoria might constitute a "zone of transition"—that is, the portion of river where the heavy pollution of the water became much less apparent to the casual observer and the river gradually assumed the essential appearance of a reasonably clean stream. The sampling station at Henry was therefore added, even though late in the time allotted to the investigation—in the hope that plankton samples from this location in this very important stretch of the river would enable us to correlate to better advantage the data already collected from La Salle; 31 miles upstream, and Chillicothe, 17 miles downstream and at the head of the long "lake" at whose outlet Peoria is located.

The station was not included in the field trips, and plankton samples only were obtained, but these were collected twice each week during the remaining six months of the study.

March, April, and May, 1922.—The spring yield of plankton averaged 710 cubic standard units. Active index organisms numbered 163 units of this total. Pollutional organisms constituted 35 per cent, and cleaner-water forms 65 per cent, of these index organisms.

¹⁸ Notably the approximate 50-50 status of the index organisms at La Salle. (See item 4.)

TABLE No. 28.—Classification of plankton organisms
STATION 196 (HENRY), MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c.c. of water									
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.
1922										
March.....	66		356			6	4		2	27
April.....	51	28	411			15	53	8		67
May.....	262	37	374			60	90	56	2	46
June.....	37	81	666	10		186	107	10	116	82
July.....	163	87	592	2		54	35	9		23
August.....	114	127	870	20		79	96	18		81
Averages:										
Spring.....	132	23	386		2	26	57	24	1	50
Summer.....	93	94	668	11		97	117	12	45	54
										710
										1,192

Predominant organisms were *Asterionella*, *Navicula*, and *Synedra* of the diatoms, *Pleurococcus*, *Scenedesmus*, and minute cells, of the green algae, a few flagellates, chiefly *Cryptomonas* and *Euglena viridis* in 6 of the 19 collections, the pollutional ciliates *Colpidium*, *Carchesium*, *Vorticella*, and *Epistylis* in six collections, with the cleaner-water ciliates *Tintinnus* and *Codonella* in five and six collections respectively. Rotifers were present in some variety but in small numbers, *Brachionus pala* and *Asplanchna* appearing in four samples each, *Monostyla* and *Polyarthra* in two samples each, and *Brachionus rubens* and *Triarthra* in one sample each. Crustacea, in nauplius form, appeared in three samples in small amount.

Attention is here called to the fact that pollutional ciliates are not present in all samples, but in about a third of them only. It is also noteworthy that two ciliates of cleaner-water preference are of frequent occurrence, being found in about a third of the samples. Finally, half a dozen varieties of rotifers gradually appear on the scene, and most of them are normally occupants of water that is fairly clean, rather than a grossly polluted water.

TABLE No. 29.—Summary of plankton findings for each month
AVERAGES AT STATION 196

Date	Plankton catch, cubic standard units in 1 c.c. of water										
	Total catch				Total organisms						
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner	
1922											
March.....	424	37	461	34,400	424	6	32	0	3	44	415
April.....	485	168	653	41,500	485	15	150	0	86	48	548
May.....	674	248	922	20,900	674	80	196	0	110	225	556
June.....	716	522	1,238	19,400	705	146	377	11	288	280	671
July.....	764	121	905	24,800	782	84	67	3	131	255	610
August.....	1,142	272	1,414	27,400	1,122	79	192	20	263	178	976
Averages for 6 months.....	704	226	932	28,070	699	56	169	6	142	173	619

June, July, and August, 1933.—The summer plankton showed quite an increase over the spring samples, the summer average total being 1,190 units, as compared with the 710 units average yield of the spring months. The summer catches contained 465 units of index organisms of which 49 per cent were pollutional and 51 per cent were of the cleaner-water varieties.

Predominating diatoms were *Synedra*, *Tabellaria flocculosa*, and *Navicula*, with a few *Asterionella* and *Fragilaria*. Blue-green algae were much more abundant than in the spring. Small fragments of *Oscillatoria* appeared in 14 of the 23 summer samples, and minute filaments of an unknown blue-green were in 15 of the samples. The green algae were the largest single constituent of the plankton in both seasons. In the summer catches the most abundant of these were *Pleurococcus*, *Tetraspora*, and *Scenedesmus* in practically every sample. *Polyedrium*, *Staurostrum*, *Actinastrum*, and *Celastrum* in 6 to 10 samples, with occasional appearance of *Dictyosphaerium*, *Pediastrum*, *Raphidium*, *Closterium*, and *Eudorina* in small amounts. Of the flagellates, *Euglena viridis* and *Cryptomonas* were the most abundant (16 and 14 samples respectively). *Phacus* and *Trachelomonas* were each in six or seven samples. The same ciliates noted in the spring samples were present, but in somewhat larger quantities. *Carchesium*, *Epistylis*, and *Vorticella* appeared in 8 samples each, *Colpidium* in 4, *Codonella* in 5, and *Tintinnus* in 1. Rotifers again showed some variety, as in the spring samples. *Rotifer tardus* appeared in 6 samples, *Brachionus pala* in 3, *Polarthra* in 2, and *Anuraea cochlearis* in 2. Crustacea were represented by *Bosmina*, *Cyclops*, and naupleii in four samples each.

Summary.—Pending further consideration in connection with the data from the next station downstream (station 179) we will here summarize the data of station 196 very briefly by the following statements:

(1) There is general increase in the amount of plankton, as compared with the yield at La Salle for the same months. The increase in spring is only 13 units over the La Salle yield, but the summer shows an increase of 507 units over the La Salle figures.

(2) The entire six months' period of investigation shows that the increased yield at this station was made up mainly of those classes of organisms which tend to flourish in water that is not heavily polluted. The greatest amount of increase was in the minute green algae.

(3) It is significant that these same figures for all catches at both stations during the six months' study show a decline in the ciliates at station 196.

STATION 179. CHILLICOTHE

At this point the river expands to a width of about a mile. This general expansion continues, with somewhat irregular shore lines, for a distance of about 17 miles downstream and constitutes "Peoria Lake." In the lower portion this lake becomes suddenly narrowed to about 650 feet and the water flows through this constricted portion with greatly increased speed. This point, "The Narrows," is at the extreme upstream portion of the city of Peoria. Below this narrow portion of the lake the stream again widens to about one-half or three-fourths mile for a distance of about 2 miles.

In the lake proper the channel is near the west shore. Most of this body of water is only 6 to 10 feet deep, particularly that large area, totaling several square miles, between the deep channel and the east shore. Many blackened snags and fragments of dead trees emerge above the water surface over portions of the lake. These are in many cases the trees that were killed by the inundating of certain low-lying areas when the addition of water and sewage from the drainage canal,¹⁷ in 1900, raised the river levels over 3 feet.

The greater portion of the lake, particularly the more shallow eastern portion of it, is essentially a backwater area, and functions as such by receiving and storing for a time the excess water of flood time, and doles it out again as the water level falls. There is, in this area, some growth of *Potamogeton*, "water weeds," and algae, but these growths are not sufficient in amount to attract attention, or even to appear to the casual observer. Such a person, inspecting the lake, would probably report it nearly or quite free from algae and similar growths. In the shallowest parts, and among the emergent stumps and snags, there is at times quite a heavy growth of surface algae easily visible for several hundred yards, but these areas are small in comparison to the great area apparently available for such growth. The extensive shallow flats along the Potomac River seem to be quite similar in structure and function to this large area which constitutes the eastern half or two-thirds of Peoria Lake. The only outstanding difference seems to be that the Potomac Flats are subject to tidal action, which enforces circulation and movement of water on those areas, the water level fluctuating meantime by about 20 inches. Yet these Potomac Flats are so completely filled¹⁸ with *Potamogetons*, eelgrass, *Ceratophyllum*, and various algae that progress with a

¹⁷ Bulletin Illinois Lab. Nat. History, Vol. IX, Art. X, p. 488.

¹⁸ "The variety and abundance of these plants is surprising and needs to be seen to be appreciated. At low tide the flat looks not unlike a great meadow, level as a floor. At such times rowboats and other small craft can with difficulty penetrate the mass." Hygienic Lab. Bulletin No. 104, p. 159.

rowboat is in many places quite difficult. There is no such condition as this in the shallow portion of Peoria Lake except in an occasional small area.

The gradient is very slight (0.26 inch per mile ¹³), and the current very slow, even at flood stage, in this lake section, between Chillicothe and Peoria. About 52 feet per minute, or 0.59 mile per hour, is the speed of the water when flood conditions (18 feet at the Peoria gage) prevail, and about half this speed at times of low water.¹⁴

June, July, and August, 1921.—In June water was practically clear and looked clean in comparison to the usual conditions observed at La Salle, 48 miles above. No odor was noticeable. A considerable amount of Potamogeton, green algae, and some blue-green algae were growing near the margins and about the emergent stumps. Portions of the low bank, particularly on the east, were thickly covered with *Arum*. A small amount of floatage, chiefly small mats of *Oscillatoria*, was observed.

A local fisherman, pointing out these mats of blue-green algae, told me that during hot weather these masses float down the river, the water bubbles and fish disappear from the channel and take refuge in the adjacent backwater area. A fish net set overnight in the channel at such time, he said, usually yields only dead fish or none at all when lifted in the morning.

From these reports it would appear that actual septic action takes place here sometimes in hot weather.

Mud samples were secured on the west side at a depth of about 10 feet near edge of channel. This mud was black, very soft, and spongy because of the gas it contained. It had a strong, offensive odor. Tubificid worms were present in large numbers, a liter of mud yielding about 2,400. Minute mussels (*Sphaeriidae*) were found in moderate numbers in this mud, about 300 less than one-eighth inch in length and 150 over one-eighth inch but less than one-fourth inch. Many shells of full-grown *Sphaeriidae* were present, but no living adults were found. Also several shells of snails were found, but no living ones. An occasional *Chironomus* larva and one leech completes the list of organisms obtained from this first liter sample of mud. (Table 30.)

¹³ Bulletin Illinois Nat. Hist. Survey, Vol. XIII, Art. XV, p. 377.

¹⁴ Determinations of current speed were made by the method of the Illinois Natural History Survey, Peoria, Illinois, 1921.

TABLE No. 30.—Bottom sediments, water surface, and stream margins

STATION 179

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growths, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1921			
June 21	(1) Black, soft, gaseous, with offensive odor; (2) Tubificid worms, 2,400; mod. numbers of young mussels	(1) Clean; moderate current; no odor; (2) masses of Oscillatoria in moderate amount and living snails floating, with small colonies of Epistylis attached.	(1) Apparently clean; beginning of Peoria Lake; offensive backwater area on east; (2) Arum, Potamogeton, and alga moderately abundant; egg masses of Chironomus numerous.
Aug. 6	(1) Black, soft, gaseous, with offensive odor; (2) Tubificid worms in moderate number (about 450); also a few young mussels.	(1) Clean; no odor; (2) Algae and duckweed in small amounts.	(1) Fairly clean; no odor; (2) submerged plants rather abundant in shallow-water zones; principal plants were Ceratophyllum, Hydrilum, and Spirogyra.
26	(1) Black, gaseous, soft; strong offensive odor; (2) Tubificid worms average 2,480; young mussels in moderate number, and a few Chironomid larvae, chiefly Tanypus, with few C. decorus.	(1) Agitated by wind; no odor; looks clean; (2) small amounts Oscillatoria and duckweed.	(1) Nearly clean; no odor; (2) Arum and duckweed abundant; Spirogyra and Oscillatoria in moderate amount.
Sept. 28	(1) Black, soft, and spongy with gas; offensive odor; (2) Tubificid worms very numerous, averaging 3,210; young mussels in moderate number.	(1) Smooth, nearly clear; slight odor; (2) no floatage.	(1) Some waste matter in marginal water, causing slight odor; (2) Arum, Sagittaria, Ceratophyllum, and duckweed (Lemna) fairly abundant.
Oct. 31	(1) Black, soft, and spongy, with offensive odor; (2) Tubificid worms very numerous, averaging 10,800; young mussels abundant, with smaller numbers of older ones, but empty shells of these very numerous; few Chironomid larvae, chiefly Tanypus, and a few C. decorus.	(1) Clear; looks clean; no odor; (2) small amount of Lemna.	(1) Fairly clean; no odor; (2) moderate amounts of Arum, Lemna, and Ceratophyllum.
Dec. 1	(1) Black and soft, but with only moderate odor; (2) Tubificid worms, 1,600; young mussels in moderate number; many shells of adults; few Chironomid larvae.	(1) Agitated by wind; no odor; (2) no floatage.	(1) Clean; no odor; (2) small amount of Arum.
1922			
Jan. 18	(1) Black, soft, with very slight odor; (2) Tubificid worms 800; a few young mussels living and many dead; a few each of Chironomus larvae and of leeches (Olimpionia).	(1) Entire lake sealed with ice, with an occasional small open place; (2) water was clear, and apparently clean.	(1) Sealed with ice; small opening about 200 feet from shore; samples obtained at this opening; (2) no plant life seen.
Mar. 15	(1) Black, soft, with slight odor; (2) Tubificid worms averaged 1,270; young mussels in moderate number, and the hollow shells of a similar quantity; a few Chironomus larvae.	(1) Smooth, slightly turbid; no odor; (2) no floatage.	(1) Clean; no odor; (2) no plants either submerged or emergent.
Apr. 5	(1) Black, very soft and spongy, offensive odor; (2) Tubificid worms numerous (940), with many egg capsules of the same; moderate number of young mussels, with equal number dead; few Chironomus larvae.	(1) Water very high, slight current, slight turbidity, no odor; (2) no floatage.	(1) Usual shore lines submerged, no odor; (2) no plants visible.
May 11	(1) Black, soft, with moderate odor; (2) Tubificid worms average 1,420; egg capsules present; few young mussels and an occasional leech.	(1) Water high; surface clean; no odor; (2) no floatage.	(1) Shore lines strewn with drift from the April floods; (2) no aquatic plants visible.

¹ Unless otherwise stated, worms are chiefly Limnodrilus and mussels practically all Sphaeridium. Data based on 1 liter of mud.

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TABLE NO. 30.—Bottom sediments, water surface, and stream margins—Continued

STATION 175—Continued

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms	Water surface: (1) Physical conditions, and (2) surface growth, etc.	Margins: (1) Physical conditions, and (2) predominating plants, etc.
1923			
June 20	(1) Black, soft, with moderate odor; (2) Tubificid worms average 1,600; moderate number of young snails, with equal numbers dead; occasional Chironomus; small colonial Pennsylvanella.	(1) Smooth and nearly clear; no odor; (2) no floatage; no surface growth.	(1) Fairly clean; no odor; (2) small amounts Arisaema, Rhipidophora, and Potamogeton, sheltering such organisms as Chironomus larva, Aulisca, Isosia, and Hyalids; many egg masses of Chironomus.
Aug. 7	(1) Black, soft, and gummy, with offensive odor; (2) Tubificid worms average 55; moderate number of young snails; few dead snails and an occasional living one.	(1) Rough on account of wind; no odor; (2) no floatage and practically no surface growth.	(1) Fairly clean; no odor; (2) Potamogeton and Rhipidophora abundant, with some Sphagnum and Chlorella; small colonies of Epistylis growing near west side of channel.
21	(1) Black, soft, gummy, with moderate odor; (2) Tubificid worms average 45; young snails in moderate number; small colonies of Epistylis on submerged stick at edge of channel.	(1) Quiet and looks clean; no odor; (2) moderate amount of surface growth Potamogeton, Sphagnum, Rhipidophora, and Chlorella in the shallow water on either side of the channel.	(1) Fairly clean; no odor; (2) Arisaema, Potamogeton, Sphagnum, and Chlorella rather abundant, with Rhipidophora, Oedogonium, and Ceratophyllum in smaller amounts; Chironomus eggs abundant; Isosia, Hyalids, Aulisca, and nematodes present; also small colonies of Epistylis.

* Unless otherwise stated, worms are chiefly Limnodrilus and snails practically all Sphaeriidae. Data based on 1 liter of mud.

July showed much the same conditions at this station. Water was nearly clear, without odor, and no floatage of consequence was seen.

Mud samples were obtained at three points,² across the channel, designated by the terms "east," "center," and "west," respectively. All mud samples were black, soft, and had an unpleasant odor. Tubificid worms were in all three samples in moderate numbers, averaging about 450 per liter of mud and being most abundant in the center of the channel. Small living bivalves were again found in rather small numbers, but no living adults, either bivalves or snails, were found.

In late August, water was nearly clear, odorless, and showed a nearly clean surface.

Mud samples taken at the three points across the channel were black, very soft, and gummy, with marked unpleasant odor. Tubificid worms were found in all samples, but were by far the most abundant in mud from center of the channel, 1 liter yielding 6,700 worms. The channel is 25 feet deep at this central point. Very small bivalves were also more numerous in this sample (over 300) and Chironomus larvae numbered 76, while only 3 and 2 of these larvae appeared in mud samples taken at east and west, respectively.

The summer plankton, 1921.—Samples were taken twice a week at this station. (See Table 54.) The average of the total summer plankton yield was 1,352 units, of which 762 units were known index

² These were the regular points for all bacteriological, chemical, and biological samples, and were so located as to represent approximately equal primes of the flowing water.

organisms. Of these, in turn, 34 per cent were pollutional forms and 66 per cent indicated cleaner water.

TABLE No. 31.—Classification of plankton organisms

STATION 178, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in million standard units) in 1 c. c. of water										
	Diatoms	Blue-green alga	Green alga	Fungi	Stenopoda	Flagellates	Ciliates	Rotifers	Crustacea	Sponges, etc.	Total
1921											
July.....	38	328	1,211	9	1	281	9	36	18	15	.....
August.....	61	189	453	7	0	123	27	6	22	23	.....
September.....	72	27	444	7	1	89	17	3	3	17	.....
October.....	203	75	285	4	1	34	45	5	0	14	.....
November.....	317	62	285	3	4	26	27	4	1	13	.....
December.....	53	3	189	0	1	31	23	0	0	47	.....
1922											
January.....	36	9	143	4	1	4	26	0	0	6	.....
February.....	104	4	196	0	1	9	97	0	0	30	.....
March.....	36	23	217	0	0	16	89	3	0	20	.....
April.....	60	1	277	1	2	15	78	1	3	15	.....
May.....	260	20	724	0	0	245	76	124	24	20	.....
June.....	46	27	595	20	0	211	27	5	145	24	.....
July.....	42	45	673	19	3	98	14	0	20	51	.....
August.....	44	215	1,027	13	0	280	21	57	4	42	.....
Average.....											.....
Summer.....	66	225	610	4	0	173	26	18	20	26	1,260
Autumn.....	143	25	286	4	2	41	27	4	1	15	999
Winter.....	60	0	166	1	1	16	56	3	0	23	256
Spring.....	124	19	449	3	1	96	76	24	9	20	826
Summer.....	55	110	764	14	1	264	51	25	63	43	1,297

Organisms making up the plankton were chiefly as follows: The diatoms, *Synedra*, *Fragilaria*, and *Navicula*, with *Talassaria fenestrata* and *Synedra biceps* each present in a very few collections. Fragments of blue-green alga were present in about half of the samples, *Oscillatoria*, *Anabaena*, and an unidentified, minute filament resembling *Beggiatoa* but slightly larger, being the chief ones. *Merismopedia* was also frequently present. Predominating green alga were *Pleurococcus*, *Calanistrum*, *Scenedesmus*, *Tetraspora*, *Pediastrum*, and minute unknown green cells, all present in practically every sample, and *Eudorina*, *Raphidium*, *Actinastrum*, and *Dictyosphaerium* appeared in about half the samples. *Botryococcus*, *Closterium*, *Polyedrium*, and *Kirchneriella* were only occasionally present. Flagellates present were *Euglena viridis*, in most of the collections, and *Phacus*, *Chlamydomonas*, and *Trachelomonas*, in about half the samples, with *Cryptomonas*, *Anthophysa*, and *Euglena oryuris*, appearing occasionally. The pollutional ciliates which were continuously present and predominant in the upper river, are noticeably fewer at this station. *Carchesium* and *Vorticella* appear in half the summer samples, *Epi-stylis* is even less often present, and *Colpidium*, *Paramacium*, and *Halteria* are found in only one sample each. *Codonella*, of cleaner-water affinities, appears in three samples. The rotifers are represented by *Rotifer tardus* in half the samples, *Brachionus* in nearly the

same number, and *Dityte* and an unknown rotifer in one or two samples each. Crustacea (*Cyclops*) appear in three samples.

Comparison with plankton data from La Salle will show that the summer plankton at station 179 is considerably greater in total quantity, shows a higher percentage of oxygen-producing organisms, and a lower content of those organisms which flourish in an environment of heavy pollution. Specifically, the index organisms at La Salle stand 48 per cent for pollution, while the collections at station 179 for the same period show, in the index organisms, 34 per cent for pollution. (See Table 6.)

This is in general accord with the testimony of the bottom sediments meantime, to the effect that, notwithstanding the general clean appearance of the water, in the absence of the grayish cast and the lack of the sewage odor (both of which are so noticeable at La Salle), yet the stream as a whole is far from clean. The large numbers of tubificid worms in the bottom mud, as well as the repulsive odor and general physical condition of this mud, constitute convincing evidence of the abundance of organic matter in these bottom sediments which, in turn, are but accumulations of such suspended matter as continuously forms a part of the overlying water. The water is not clean, notwithstanding its favorable appearance to the casual observer.

September, October, and November, 1921.—In late September the water was nearly clear, but contained very fine suspended matter in rather large amount. Commercial fishing had begun, and about 75 pounds of carp were taken daily. In shallow water near the west shore the submerged plant *Ceratophyllum* was fairly abundant. Duckweed and green algae were also present in moderate quantity. The deep water of the channel was free of algae or other growth. There was no surface floatage. A small amount of septic action was indicated by the rising of a few bubbles from various portions of the channel. When the bottom sediments were disturbed by the mud sampler, great quantities of bubbles arose.

Mud samples taken at three points (east, center, and west) in the channel, were black, sticky, soft, and stinking. That on the west side was slightly more granular in nature than the other samples. All samples contained tubificid worms, the counts per liter of mud being 60, 9,300, and 280, from east, center, and west, respectively. All samples also contained young bivalves (*Sphaeriidae*), the center sample yielding about 250, and the other samples less than half as many. No adult *Sphaeriidae* were found in any of the samples, but many shells of adults were present. Of the young (all less than one-fourth inch in length), only a very few—about 5 per cent—were dead. Chironomid larvae were found in small numbers in the cen-

ter and west samples. These were about equally divided between *C. decorus* and a species of *Tanypus*.

In late October and early November, water was nearly clear, surface clean, and no odor could be detected. Small amounts of green algae and *Ceratophyllum* were in the more shallow water near east and west margins. Mud obtained at the usual three sampling points was black, sticky, gaseous, and had offensive odor. That from center of channel contained very large numbers of shells of adult *Sphaeriidae*, and in the mud intermixed were extraordinary numbers of tubificidae, many of these being smaller than the adult worm. The total yield from about 1 liter of this mud was slightly over 30,000 worms. Of these, 72 per cent were *Limnodrilus* and the remainder were *Tubifex*. Mud samples from east and west yielded 1,400 and 600 worms, respectively. Large amounts of gas rose to the surface when bottom sediments were disturbed by the mud scoop.

This mud sample from center of the channel also yielded 2,600 young bivalves (*Sphaeriids*) of less than one-fourth inch length. There were only a very few of the very young ones (those about one-eighth inch in length). On the contrary, the sample from east yielded 800 of these minute bivalves and 400 of the quarter-inch size, and the west sample contained over 1,500 of the very young and less than a dozen of the larger size. Apparently these were all *Sphaeriids*, but empty shells were very abundant. It seems obvious that conditions are such at this point that these bivalves, somewhat sensitive to sewage pollution, are unable to survive these conditions long enough to enable the majority of them to reach mature size.

This fact is attested by the numerous shells of adults, by the very few living adults, and meantime the relatively large numbers of living young and partly grown. There is some factor in the environment that causes an increasingly heavy mortality as the young mussels pass the stage of infancy, some reaching medium growth but very few attaining maturity.

The only other organisms yielded by these mud samples were chironomid larvae in moderate numbers at east and center (92 and 160 respectively), but very few (only 4) from the west sample. The large majority of these larvae were *Tanypus* (unidentified as to species), this variety numbering 247 of the total of 252. The remaining five were *C. decorus*.

The autumn plankton, 1921.—Average total plankton yield was 673 cubic standard units, of which 291 units were index organisms. These index organisms in turn showed 35 per cent pollution forms. (Table 6.)

The principal diatoms in the autumn plankton were *Synedra* and *Tabellaria fenestrata* in three-fourths of the samples, and *Melosira* and *Navicula* in about half of them. *Fragilaria*, *Tabellaria flocculosa*, and *Asterionella* were frequently present also. The blue-green algae

were represented chiefly by minute fragments in less than half the 26 autumn samples. The green algæ included *Pleurococcus*, *Scenedesmus*, and minute, unknown algal cells, in practically every sample, *Tetraspora*, *Raphidium*, and *Pediastrum* in about half the samples, and *Celastrum*, *Actinastrum*, *Botryococcus*, *Oosterium*, *Staurostrum*, *Dictyosphaerium*, and *Pandorina* frequently present in moderate or small quantities. Fungi were very rare or absent. The rhizopods *Diffugia*, *Arcella*, and *Amæba* appeared in four or five samples. Of the flagellates, *Cryptomonas*, *Euglena viridis*, and *Chlamydomonas* were of frequent occurrence, but even these appeared in less than half the collections, while *Phacus* and *Tracehlomonas* were only occasionally present. In like manner, the ciliates were not continuously present, nor abundant, in comparison with their predominance in the upper river. The recognized pollutional forms were not conspicuously abundant. *Vorticella* was present in 13 of the 26 samples, *Carchesium* and *Epistylis* in six samples each, and *Colpidium* in five. Meantime *Codonella*, a resident of cleaner water, appeared in eight of these samples. The rotifers were also few, *Rotifer tardus* being found in eight samples and an unidentified rotifer in three samples. Naupleii of crustacea appeared in four samples. (Table 31.)

December, 1921, January and February, 1922.—Two winter trips were made to this station, one in early December and the other in mid-January. At the time of the first visit the water was so rough on account of wind that no mud samples could be taken at center of the channel. There was no surface floatage, and no odor was perceptible. Plant life was negligible in quantity, or if present could not be seen in the turbulent water. A little *Arum* still grew along the shore.

Mud samples at east and west were black, soft and spongy, and had moderate odor. Only a very few tubificid worms appeared in the east sample, but the west sample contained about 3,600 worms, 84 per cent of these being *Limnodrilus* and the remainder *Tubifex*. This west sample also yielded about 1,800 young *Sphæriidæ* of which 92 per cent were living. There were many shells of adult *Sphæriidæ*, but no living adults. A dozen-odd *Chironomus* larvæ completed the catch from this liter sample of mud. Two of these were *C. decorus* and the remainder were the unknown *Tanypus*.

The other mud sample contained about 300 young *Sphæriidæ*, most of them living. No living adults were found, no *Chironomus* larvæ, and only a very few worms.

In mid-January the lake was sealed down with ice several inches thick. The swift water in the "Narrows," at the lower end of the lake, was not frozen. With the exception of this and of a half dozen small unfrozen areas of perhaps four or five square rods each, the seal of ice seemed to be intact over the entire lake. Fortunately one of these small unfrozen places was at the sampling point at 179, on the

west side. Ice 6 or 8 inches thick extended from shore, but about 250 feet out this open place was approached by means of a "duckboat" (on account of the thin ice where the current was strong) and samples obtained.

The water was clear, looked clean, and was without odor. A light snow covered the ice, so presence of submerged vegetation could not be ascertained.

Mud obtained at this west point was black, with some light-colored mud mixed with it. No odor could be detected. The water was about 10 feet deep here at this time.

This liter of mud yielded 800 tubificid worms, about 50 small living bivalves (*Sphaeriidae*), many dead ones, 7 living adult snails, 22 shells of snails, 2 Chironomus larvæ, and 18 leeches. The two Chironomus larvæ were *C. lobiferus*, and *Tanypus* of unknown species respectively. The leeches were all of one kind, a variety (unidentified) of *Glossiphonia*.

It seems plain that low temperatures have not entirely stopped biological activities here, although the numbers of organisms have been diminished somewhat, and in all probability their activities have been decreased somewhat also. Examination of the tubificid worms showed that their alimentary canal was apparently as well filled as was that of the same kind of worm taken at this same point the following spring (March). Whether this well-filled alimentary tract indicated the usual continuous foraging of this worm, or whether, in possession of a good supply of food, the worm was relatively inactive during the cold weather, is of course not known.

The winter plankton.—The 26 winter samples yielded an average total plankton of 339 units. (This was about half, or 52 per cent, of the average winter plankton at La Salle, 48 miles upstream). The total of 339 units furnished 100 units of index organisms, these showing 70 per cent pollution forms and 30 per cent cleaner-water forms.

Leading diatoms in this winter plankton were *Asterionella*, in half the samples, and *Synedra*, in about a third of them. The *Tabellarias*, *Fragilaria*, *Melosira*, and *Navicula* were occasionally present. As a class the diatoms made a poor showing. The blue-green algæ appeared in only four or five samples. Green algæ consisted mainly of *Pleurococcus* and minute unknown cells, in every sample. *Scenedesmus*, *Tetraspora*, *Raphidium*, and *Staurastrum* appeared in five or six samples each. Of the rhizopods, *Diffugia* and *Arcella* were found a few times. Flagellates were infrequent, *Euglena viridis*, *Phacus*, and *Trachelomonas* appearing three or four times in the 26 samples. Ciliates were more abundant, the pollutional forms *Colpidium*, *Carchesium*, and *Epistylis* appearing in 20, 15, and 11 samples, respectively, and *Vorticella* in 8. The cleaner water ciliate *Odonella* was not found at all. Only a very few rotifers appeared in these winter collections. *Rotifer tardus* was found twice, *Brachionus pala* once,

and *Polyarthra* once. Crustacea were absent, with the exception of an occasional nauplius form.

March, April, and May, 1922.—In mid-March the water was somewhat turbid, with surface smooth and free from floatage. There was no odor. Algae and other aquatic plants were apparently absent.

Mud samples taken at the usual sampling points were black, soft, and had a slight odor. Tubificid worms were comparatively few in east and west samples (350 and 150, respectively), but were numerous at center of the channel, 1 liter of mud containing 3,300 worms. This center sample also yielded nearly 1,000 dead young bivalves (*Sphaeriidae*), 50 living ones, and 2 *Chironomus* larvae.

The east sample contained even fewer living *Sphaeriidae*, but the west sample yielded over 1,600 living and nearly 600 dead. More specifically, it was noted, in the total yield of *Sphaeriidae* from this sample, that of 1,780 very young bivalves (one-eighth inch or less in length) the ratio of living to dead was 9 to 1. Of the 225 slightly larger ones (up to one-fourth inch in length) the ratio of living to dead was 1 to 11. Finally, in the 200 that were nearly or quite full grown (one-fourth inch to one-half inch in length) the ratio of living to dead was 1 to 24. This condition of affairs would seem to indicate that the young of these bivalves are successfully produced in fairly large numbers, but the prevalence of unfavorable environment is shown in the fact that 1 out of 10 dies almost immediately. Likewise the struggle is too much for those that survive this first stage, for 11 out of 12 of the half-grown ones succumb. Finally, of the relatively few that attain essential maturity, only 1 in 25 survives to reproduce its kind in this apparently unfavorable environment.

Relative to this environment, and the resulting heavy mortality in the *Sphaeriidae*, confirmatory evidence is found in the study²¹ of the Big Vermilion River, by F. C. Baker, who comments on the entire absence of *Sphaeriidae* in a heavily polluted portion of the stream, though abundant above the point of pollution and occurring again several miles below. The investigator cited remarks: "These mussels are characteristic mud dwellers and their absence from the intervening territory in the stream is striking evidence of the unfavorable conditions on the bottom." It would thus seem that the environment at station 179 is very unsuitable for *Sphaeriidae*, and that the chief unfavorable factor is the heavily polluted bottom sediments in which these mussels must dwell.

In April the water was very high, due to rains. There was slight current, no surface floatage, and water was slightly turbid. No aquatic vegetation was seen. No odor was perceptible.

Mud samples taken at east and west points were black, soft, and spongy, and had marked, offensive odor. No sample was taken at

²¹ Illinois Biological Monographs, Vol. VII, No. 2, April, 1922, p. 52.

center of channel. East and west samples yielded about 2,000 and 1,000 tubificid worms, respectively. There were numerous egg capsules also, indicating that the worms were in suitable environment and were propagating.

In May the water was still somewhat above the normal levels, and the shore lines were strewn with drift left by the very high water of the April floods. The water was slightly turbid and without odor. No surface floatage, and no algae or other submerged plants were seen.

Mud samples secured at the usual three points were black, soft, and had noticeable odor. The sample from center of channel was somewhat granular in nature, and the odor was scarcely perceptible. This was in all probability due to the flushing out of the lighter, gaseous surface muds by the recent high water. All three samples yielded tubificid worms approximately 1,000, 3,000, and 300, at east, center and west, respectively. It seems evident that the flood current, which was sufficient to remove the lighter muds from the center of the channel, was meantime unable to remove the resident tubificid worms to any great extent. This is probably due to the fact that these worms are usually well embedded in the mud, with only the posterior third (or less) of their body protruding. Moreover they instantly dart more deeply into the mud at the least disturbance. The mud must be removed bodily in considerable amounts in order to dislodge the adult worms. Comparatively few young living *Sphaeriids* were found in these mud samples, and only an occasional living adult.

TABLE NO. 32.—Summary of plankton findings for each month
AVERAGES AT STATION 179

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms				Total organisms			
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutinal	Cleaner		
1921												
July.....	1,047	337	1,074	11,800	1,047	251	78	0	337	703	946	
August.....	681	328	909	15,300	673	107	121	7	304	331	873	
September.....	613	98	711	16,000	608	57	39	8	103	190	406	
October.....	549	38	633	15,700	545	21	64	4	100	300	333	
November.....	587	87	674	31,400	585	30	48	3	100	167	405	
December.....	234	91	325	32,100	234	17	74	0	44	41	240	
1922												
January.....	192	71	303	13,300	198	4	66	4	80	39	178	
February.....	366	124	430	13,500	305	9	115	0	107	20	303	
March.....	374	130	504	30,700	374	16	134	0	92	31	383	
April.....	350	106	456	57,000	349	15	93	1	28	71	320	
May.....	1,065	819	1,584	84,200	1,057	245	275	8	134	566	855	
June.....	874	445	1,119	18,700	854	211	234	30	130	379	603	
July.....	800	301	1,010	16,400	799	68	103	9	93	340	578	
August.....	1,399	415	1,714	13,900	1,388	376	130	13	448	650	711	
Average for 11 months.....	565	264	799	34,840	590	86	118	5	123	227	451	

The spring plankton.—The 25 twice-a-week samples taken here during the spring months yielded an average total plankton of around 860 cubic standard units. The average of index organisms was 321 units, 27 per cent of these indicating heavy pollution and 73 per cent indicating cleaner water.

This spring average of 860 units was two and one-half times the average winter yield here and is an increase of 27 per cent over the spring average for La Salle, 49 miles upstream.

The most abundant diatom in the spring collections was *Synedra*, in 18 collections. *Asterionella* appeared in 10 collections, and *Tabellaria fenestrata*, *T. flocculosa*, *Melosira*, *Synedra biceps*, *Navicula*, and *Fragilaria*, in four or five collections each. Fragments of blue-green algae were only occasionally present. Leading green algae were *Pleurococcus* and minute green cells, in practically every collection, *Scenedesmus* and *Tetraspora* in nine collections, *Raphidium*, *Polyedrium*, and *Actinastrum* in five, and occasional occurrence of *Staurastrum*, *Calostrum*, *Closterium*, *Rotryococcus*, *Pediastrum*, *Eudorina*, and *Gonium*. Of the flagellates, *Euglena viridis* and *Cryptomonas* were found in 10 collections, and *Trachelomonas*, *Phacus*, and *Chlamydomonas* in 3 or 4 samples. The pollutional ciliates *Carchesium*, *Colpidium*, and *Vorticella* each appeared in 9 samples, *Epiplatys* in 5, and *Codonella* in 2. Rotifers were few in number but they represented considerable variety, there being 3 samples containing *Rotifer tardus* and *Anurxa cochlearis*, 4 collections showing *Brachionus pala*, 5 containing *Asplanchna*, with *Polyarthra* and *Brachionus rubens* appearing in a single sample each. Crustacea were represented by *Cyclops* and *Bosmina* in one sample each and naupleii in two samples.

June, July, and August, 1922.—In late June the water was nearly clear, and without odor. No floatage appeared on surface, and no algae or other submerged plants were observed. A small amount of *Arum* emerged from the very shallow water near margin. Attached to these stems were a few each of *Chironomus* larvae, the crustacea *Asellus* and *Hyalella*, and leeches.

Mud samples taken at east, center, and west were black, soft, with noticeable odor, and contained moderately large numbers of tubificidae, except the west sample, this yielding only 22 worms. East and center samples contained 2,500 and 1,000 worms, respectively. All samples contained a few small living *Sphaeriidae* with some living adults, and the usual large proportion of dead and of shells. Two *Chironomid* larvae were taken and small amounts of *Plumatella*.

In late July and early August the customary clean appearance of the water was in evidence. Water was slightly turbid, without odor and free from floatage. Moderate amounts of *Potamogeton* were obtaining a hold in the more shallow water, and the green

algae *Hydrodictyon*, *Spirogyra*, and *Cladophora* were present in moderately large amounts in these shallow places. The blue-green *Oscillatoria* was also present. Chironomid larvae and certain caddisfly larvae (*Hydropsyche*) were found in small numbers among these submerged plants.

Mud samples taken at east, center, and west were black, soft, and spongy, and had a marked offensive odor. Considerable amounts of gas were released when the mud sampler disturbed the bottom. All samples contained relatively small numbers of tubificid worms. Young bivalves (*Sphaeriidae*) were in all samples. About a dozen adult living *Sphaeriidae* were found in these three samples and one living snail.

In late August the water was almost clear, without odor, and the surface without floatage. The stream looked clean. There was nothing unsightly or repulsive in the channel proper. In the shallow margins considerable amounts of algae and *Potamogeton* appeared on and near the surface. The principal algae were *Spirogyra* and *Cladophora*, with *Hydrodictyon*, *Stigeoclonium*, and *Ceratophyllum* in smaller amounts. The blue-green alga *Oscillatoria* was also present in noticeable amount. A vigorous growth of *Arum* was conspicuous near the west margin in shallow water. Chironomid egg masses were very abundant, attached to water weeds, emergent snags, or other support. Several leeches were found in a mass of algae attached to an emergent snag. Other inhabitants of alga masses were a few each of nematode worms, tubificid worms, *Ceratopogon* larvae, the crustacean *Asellus*, *Bosmina*, and *Hyalella*, the minute green alga *Closterium*, and various diatoms.

Small colonies of the pollutional ciliate *Epistylis* were found growing on leaves and stems of *Potamogeton*. Colonies were also found attached to an upright pole which had been placed in the edge of the channel 10 weeks previously. All these colonies were small, some containing only 2 or 3 monads each, some 8 or 10 monads, others 20 or more, and the largest colony found contained about 100 monads. A heavy wire, known to have been in the water only three weeks, also showed small colonies of this ciliate.

Mud samples taken at east, center, and west were black, soft, and spongy and had marked unpleasant odor. Small numbers of tubificid worms were found in each sample, 71, 40, and 18, respectively. Small living bivalves (*Sphaeriidae*), numbered 300, 1,100, and 400, respectively, in the three samples, with only a very few adults living. Many adult shells were present, and one sample contained a score or two of snail shells, but no living snails.

The summer plankton, 1922.—The average total yield of the 26 collections was approximately 1,300 cubic standard units, of which about 650 units were index organisms. These in turn showed 34 per

cent of pollution forms and 66 per cent of organisms associated with cleaner water.

The total yield as given above is an increase of 51 per cent over the spring total of this same station.

The diatom content of these collections consisted of *Synedra* in nearly every sample, *Navicula* in 10 samples, and *Tabellaria*, *Melosira*, and *Fragilaria* of occasional occurrence. Blue-green algae displayed considerable variety, *Oscillatoria*, *Anabaena*, and an unidentified filamentous form being present in 9 or 10 samples each, *Merismopedia* in 7, and *Nostoc* in 3. Green algae were predominant as to quantity and variety over all other groups of organisms. *Pleurococcus*, minute unknown cells, *Scenedesmus*, *Tetraspora*, *Actinastrum*, and *Celastrum* were in practically every sample. *Polyedrium*, *Raphidium*, *Staurostrum*, *Botryococcus*, *Pediastrum*, and *Richteriella* were frequently present. *Closterium*, *Dictyosphaerium*, *Gonium*, and *Pandorina* appeared occasionally. As a class, the quantity of these minute green algae exceeded the spring yield of these organisms at this same station by about 70 per cent.

The flagellates were moderately abundant. *Euglena viridis* and *Cryptomonas* appeared in about three-fourths of the samples, *Phacus* in half, and *Trachelomonas* occasionally. The ciliates were not abundant as a class. *Colpidium* and *Vorticella* appeared in 7 samples each, *Codonella* in 6, *Carchesium* in 4, *Epistylis*, *Paramacium*, *Stentor*, and *Tintinnus* in 1 sample each. Rotifers were occasionally in the collections, *Rotifer tardus* appearing in 7 samples, an unidentified species in 2, *Diastyla* in 2, and *Polyarthra*, *Triarthra*, *Asplanchna*, *Brachionus rubens*, *B. angularis*, and *Philodina* in 1 sample each. The crustacea were relatively numerous for a part of the season, nauplius forms appearing in 13 samples, *Cyclops* in 9, *Boemina* in 4, and *Daphnia* in a single sample. The large size of these organisms, as compared with the rotifers, ciliates, etc., gives them a quantitative significance even when they are present in small numbers.

Summary and discussion.—The water at station 179, at the head of Peoria Lake, looks clean, is without odor, and is usually clear at practically all seasons excepting at times of flood. This apparent cleanliness to the casual observer has doubtless been a factor in the establishing of numerous summer cottages along the west margin and the general use of the water for swimming and boating.

Mud samples taken nearly every month and plankton samples taken twice a week over a period of 14 months unite in the verdict that the water is not as clean as it appears to the casual observer. The bottom sediments, accumulated from suspended matter in the water, continuously show a condition of heavy pollution. This is further emphasized by the persistent abundance of such organisms as are invariably found only in polluted mud, and the absence mean-

time of such organisms as are commonly found on the bottoms of clean streams. The very heavy mortality of the small mussel (*Sphaeriidae*) already noted is also to be regarded as an indication of the polluted condition of the bottom sediments.

The water itself, having movement, some overturn, and considerable aeration in consequence, possesses an advantage over the bottom mud and shows accordingly a greater degree of purification. The plankton organisms indicate that the water, though far from clean, is not in the grossly polluted condition continuously shown by the mud. Distinctively pollutional organisms average 35 per cent in autumn, 70 per cent in winter, 27 per cent in spring, and 34 per cent in summer. The remainder of the plankton²² is made up of such organisms as are invariably found in water that is not highly polluted; hence are classed as cleaner-water organisms. These constitute about two-thirds of the known index organisms at this station in autumn, spring, and summer, and about one-third in winter, according to our records for 14 months.

Significance is attached to the statement, on page 125, that colonies of *Carchesium* were found attached to poles which had been placed in the channel 10 weeks previous to the time of this collection. This organism is of well-known pollutional habitat, and practically carpets the bed of the Joliet section of the river. Its food apparently is bacteria.

In the heavily polluted habitat of the upper river, colonies and masses of this organism often attain a length of 6 to 10 inches, containing countless numbers of individuals. In this partly purified water at station 179, no large colonies were found, the largest containing only about 100 individuals. Such a colony is much smaller than the head of an ordinary pin. Only by careful search were these minute colonies discovered, as most of them contained less than a dozen individuals each.

It is thus apparent that, though the water at station 179 is unable to support this pollution-loving organism to the extent that it will form large colonies, as in the upper river, yet it is significant that sufficient pollution is still present to enable this ciliate to exist and to develop small colonies on resident *Potamogeton* stems and very minute colonies on recently placed poles in the channel.

Compared with corresponding plankton data from La Salle, 49 miles upstream, the water at station 179 shows distinct improvement. Not only is the average percentage of pollution organisms smaller at the latter station but the make-up of the plankton indicates progressing purification. The cleaner-water ciliate *Codonella* occurs frequently, rotifers appear in considerable variety, instead of being limited to the one pollutional kind abundant in the upper river, and for the first

²² Reference is made to the "index organisms" only.

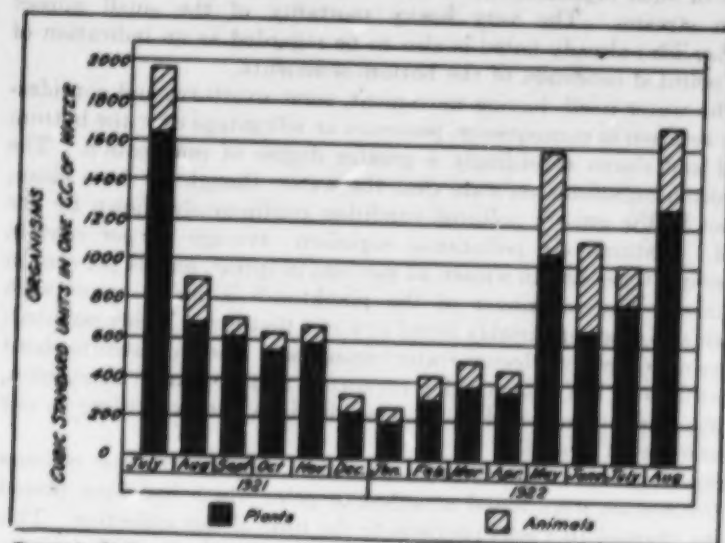


FIGURE 9.—Station 178. Monthly averages of weekly plankton catches expressed as plants and animals

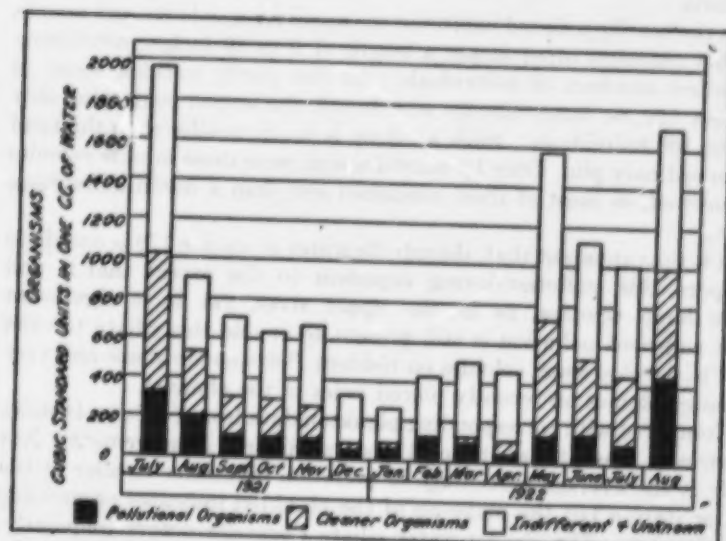


FIGURE 10.—Station 178. Monthly averages of weekly plankton catches expressed as pollutional, cleaner, and indifferent

time crustacea are sufficiently numerous in summer to constitute an appreciable portion of the plankton content.

In the total plankton, the percentage of oxygen producers is high, averaging 92, 75, 81, and 87 per cent in autumn, winter, spring, and summer, respectively. Furthermore, as the water now enters upon its very leisurely 17-mile passage through Peoria Lake, it must necessarily come to pass that the various agencies of biological purification becoming ascendant at the head of the lake will now be further strengthened. Sedimentation will proceed to advantage; reoxygenation will go on rapidly by reason of the very large surface exposure; the cleared water will admit abundant light for growth of chlorophyll-bearing organisms, with the consequent production of synthetic oxygen, and this, in turn, will make for the effective operation of bacteria in reducing the organic matter of the water.

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CHAPTER VII

THE LOWER RIVER, SUMMARY BY STATIONS

STATION 166 THE NARROWS

The mile-wide lake suddenly narrows to about 650 feet at this point, and the stream flows swiftly for a few hundred feet, then resumes its usual slow movement as the banks again diverge and the river widens to about half a mile. A wagon bridge spans the stream at this narrow point, and our samples were obtained from this bridge. No samples of bottom mud were attempted on account of the rapid current, and also because of the difficulty of handling a rowboat successfully at this point.

The water near this lower end of the lake would presumably show some improvement on account of the slow passage and extensive exposure to air and sunlight incident to the 13-mile passage through this mile-wide expansion known as Peoria Lake. Moreover any real improvement in the condition of the water should be reflected in the relative proportions of the constituents of the plankton.

Plankton samples were taken twice a week from mid depth at three points in the channel, east, center, and west.

July and August, 1921.—The total plankton yield for these summer months averaged about 1,900 cubic standard units, a gain of 41 per cent over the yield at the head of the lake meantime. Known index organisms averaged 1,159 units, 31 per cent of these indicating pollution and 69 per cent being those organisms usually associated with cleaner water. The total plankton showed 79 per cent of oxygen producers.

TABLE No. 33.—Summary of plankton findings for each month

AVERAGES AT STATION 106

Date	Plankton catch, cubic standard units in l. c. of water										
	Total catch				Total organisms						
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indefinite and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutious	Cleaner	
1901											
July	1,084	1,197	2,281	15,700	1,641	441	737	13	660	1,084	1,508
August	1,085	170	1,255	25,000	1,036	106	64	7	60	513	634
September	660	361	1,021	15,000	641	124	126	6	120	413	686
October	578	157	735	20,000	668	109	34	6	118	343	357
November	529	69	598	17,000	608	36	80	4	18	186	265
December	338	36	374	26,000	536	19	7	0	10	63	161
1902											
January	396	45	441	14,000	396	37	51	0	20	85	120
February	367	36	403	13,000	368	8	30	3	31	97	176
March	830	47	877	42,700	512	19	38	11	18	90	636
April	573	83	656	25,000	573	27	40	0	4	16	510
May	765	660	1,425	15,000	765	373	201	6	147	345	690
June	686	651	1,337	15,000	694	323	310	3	130	361	636
July	1,378	343	1,721	27,700	1,205	365	70	16	124	660	1,221
August	1,706	663	2,369	26,000	1,697	666	337	6	366	1,197	693
Average for 11 months	678	280	958	23,000	671	131	127	5	96	290	497

TABLE No. 34.—Classification of plankton organisms

STATION 106, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in l. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates ¹	Rotifers	Crustaceans	Specim. etc.	
1901											
July	45	641	1,108	13	6	663	3	177	617	11	.....
August	31	91	906	7	6	108	5	39	18	10	.....
September	37	77	686	7	13	154	64	9	13	10	.....
October	200	133	467	9	1	108	14	0	3	16	.....
November	157	41	204	6	0	30	17	4	3	0	.....
December	46	18	264	0	0	39	3	0	1	3	.....
1902											
January	37	14	167	0	1	16	31	3	1	6	.....
February	46	31	177	3	0	6	13	0	0	10	.....
March	66	0	843	11	0	13	13	3	1	19	.....
April	66	17	263	0	0	33	36	3	0	0	.....
May	148	28	614	0	3	277	61	69	161	34	.....
June	36	17	673	3	0	341	66	6	177	34	.....
July	30	161	1,106	16	3	569	37	7	31	11	.....
August	30	168	1,319	6	1	673	94	47	20	20	.....
Average:											
Summer	34	337	1,010	9	8	263	4	66	226	14	1,600
Autumn	140	79	647	6	6	96	30	4	7	13	643
Winter	45	19	310	1	0	14	13	1	1	6	300
Spring	165	18	437	4	1	118	46	24	97	16	600
Season	37	96	1,063	9	1	260	79	21	36	26	1,706

¹ All ciliates in all collections for entire period averaged 44 per cent cleaner forms (Cochranella and Tintinnus) and 56 per cent pollutious forms (Carchesium, Colpidium, etc.).

Diatoms were not abundant. *Synedra* appeared in half the samples. *Tabellaria flocculosa* and *Navicula* were frequently found in small numbers. Blue-green algae were found in larger quantity, the list including *Nostoc*, *Anabaena*, *Oscillatoria*, and *Merismopedia*, with occasional occurrence of a minute unidentified species. Green algae were quite abundant, *Pleurococcus*, *Culastrum*, *Actinastrum*, *Scenedesmus*, *Raphidium*, *Pediastrum*, *Tetraspora* and minute unknown green cells all appearing in practically every sample, with occasional occurrence of *Closterium*, *Botryococcus*, *Pandorina*, *Crucigenia*, *Staurastrum*, and a few others. The variety exhibited by this list of green algae is worthy of note.

Fungi were practically absent. Rhizopods (*Diffugia* and *Arcella*) were very infrequent. Flagellates were moderately abundant, the chief ones being *Euglena viridis*, *Chlamydomonas*, *Phacus*, *Trachelomonas* and *Cryptomonas*. *Euglena deses*, *E. oxyuris*, *E. spirogyra*, and *Anthophysa* were occasionally present.

Ciliates were relatively few. The pollutional forms *Carchesium* and *Vorticella*, were in about half the samples, the cleaner-water *Codonella* being also present in about the same number. *Colpidium*, another pollution indicator, appeared in 2 samples, and *Tintinnus*, of cleaner-water preferment, in 4 samples. Rotifers were few in numbers but their larger size as compared with the ciliates gave them much greater quantitative importance. Several varieties are present. *Brachionus pala* appears in 8 samples, *B. rubens* in 4, and *B. bakeri* in 2. Certain forms usually found in polluted water, *Rotifer tardus*, *R. actinurus*, and *Triarthra*, are found in 3 samples each. Other varieties such as *Polyarthra*, *Anuraea*, *Notus*, and *Monostyla* are occasionally present. As a whole, the rotifers are quantitatively four times as great as in the collections taken at the same time at the head of the lake (station 179). (See Tables 31 and 34.)

Crustacea are quantitatively important also, showing a heavy increase over the collections at station 179. Apparently the quiet water of the lake has provided a very suitable environment, for the average content at this station is 225 standard units as compared with an average yield of only 26 units at station 179 for the same period. *Cyclops*, *Bosmina*, *Daphnia*, *Chydorus*, and nauplius forms were the crustaceans found in these samples.

September, October, and November, 1921.—The average yield of total plankton was about 850 units, of which 400 units were known index organisms. These, in turn registered 21 per cent for pollution and 79 per cent for cleaner water. The total plankton average is an increase of 25 per cent over the average yield for the same period at the head of the lake.

Diatoms in this autumn plankton were moderately abundant especially in October and November. The average diatom content

during the autumn was 143 units, as compared with 35 units (average) during the summer. *Synedra* was present in practically every sample, *Tabellaria* and *Nasirella* in a third of the samples, with *Fragilaria*, *Melosira* and *Asterionella* occasionally present. Of the blue-greens, *Merismopædia* and minute fragments of a filamentous form appeared in a third of the collections. *Anabaena* and *Oscillatoria* were frequently present. Green algae were again abundant, as to kinds, but only moderate as to quantity. *Pleurococcus*, minute cells, *Scenedesmus*, and *Tetraspora*, were in practically every sample. Of less frequent occurrence were *Pediastrum*, *Actinastrum*, *Polyedrium*, *Culastrum*, *Dictyosphaerium*, *Staurastrum*, *Raphidium*, *Botryococcus*, and *Pandorina*. The average volume of this imposing autumn list was only 447 units, however, as compared with the summer average of 1,010 units. November showed the smallest yield. It seems obvious that the gradual decrease of these algae is the biological response to the increasing cold as winter approaches.

The flagellates show a similar decrease, averaging 262 units in summer, but only 98 units in these autumn collections. But even this was more than twice the average flagellate content of samples taken at the head of the lake during the same period. *Euglena viridis*, *Chlamydomonas*, *Cryptomonas*, *Trachelomonas*, *Phacus*, and *Euglena oxyuris* were the most abundant flagellates.

The ciliates averaged 39 units, a heavy increase over the summer samples, which averaged only four units. However, the cleaner-water ciliate *Codonella* appeared in more of the samples than did the pollutional forms. Also it should be remembered that during the cooler weather decomposition processes in the water proceed more slowly, thus, on account of movement of the water, transferring to a point farther downstream the sanitary condition and corresponding organism content such as we usually find some distance above the given point during the warmer seasons. These two facts seem to offer reasonable explanation why the ciliate content at this station is increased at this time. The very cold weather of winter is known to be attended with a general decrease of nearly all forms of life, including the plankton. But the medium cold of autumn apparently is not sufficient to bring about this wholesale decrease of activity.¹

In addition to *Codonella*, the pollution ciliates *Carchesium*, *Vorticella*, and *Colpidium* appeared in about half a dozen each of the total of 26 autumn samples.

Rotifers were all but absent. *Brachionus pala* in two samples, and *B. rubens*, *Rotifer tardus*, and *Mastigocerca* in one sample each, constituted the list. Crustacea were also few in number, *Cyclops* and nauplius forms appearing in seven or eight samples.

¹ Diatoms usually increase during the cooler weather of autumn, but are, as a rule, not abundant during warm weather.

December, 1921, January, and February, 1922.—The 26 twice-a-week winter collections averaged a total plankton of 306 units, of which 63 units were known index organisms. These index organisms were made up of 29 per cent pollution forms and 71 per cent cleaner-water forms.

In this light winter plankton the chief diatoms were *Asterionella*, in 16 samples, *Synedra* in 13, *Tabellaria* in 5, and occasional presence of *Fragilaria*, *Navicula*, and *Synedra radians*. Blue-green algæ were not abundant. Green algæ were similarly scarce, averaging less than half the autumn yield per sample. The chief ones were the usual *Pleurococcus*, minute unknown cells, *Scenedesmus*, *Tetraspora* and *Raphidium*. The rhizopods *Diffugia* and *Arcella* appeared in 2 samples each. Flagellates were found in a few of the 26 samples, *Cryptomonas* being in 9, *Chlamydomonas* in 4, and a few other forms in one or two samples, the total flagellate content averaging only 14 units. Ciliates were found in a larger number of samples, but the average ciliate content was but 12 units. *Colpidium* was most abundant (13 samples), *Carchesium* appeared in 7, *Vorticella* in 5, *Codonella* in 4. *Epistylis* and *Paramacium* appeared once or twice. Of the rotifers, *Brachionus* was found in a single sample and an unidentified rotifer in two samples. Crustacea were represented by naupleii only in three samples.

March, April, and May, 1922.—The samples taken during these spring months numbered 24. Average total plankton content was approximately 800 units, more than two and one-half times the average winter yield. The 276 units of known index organisms showed 20 per cent of pollution forms and 80 per cent cleaner-water forms.

Asterionella and *Synedra*, appearing in about two-thirds of the 24 samples, were the most abundant diatoms. *Tabellaria flocculosa*, *Fragilaria*, and *Navicula* were found in three or four samples each. Blue-green algæ were of only occasional occurrence. Green algæ were moderately abundant, averaging more than twice the winter yield. *Pleurococcus* and minute, unknown cells were in every sample. *Raphidium*, *Tetraspora*, *Scenedesmus*, *Actinastrum*, *Polyedrium*, and *Coelastrum* were of less frequent occurrence. Flagellates, sparingly present in March and April, showed a heavy increase in May, so that the average flagellate content for the three spring months was eight times as much as the winter average. The leading organisms were *Cryptomonas*, *Euglena viridis*, *Phacus*, *Chlamydomonas*, and *Trachelomonas*.

Ciliates were moderately abundant, *Vorticella* appearing in 12 samples, *Carchesium*, *Colpidium*, and *Epistylis* in half a dozen each. The cleaner-water ciliates *Codonella* and *Tintinnus* were found in three samples each.

The rotifer content showed quite a variety. *Brachionus pala*, *Asplanchna*, and *Polarthra* were in five samples each, while *Rotifer tardus*, *Anuraea cochlearis*, *Monostyla*, *Pterodina*, and *Brachionus muelleri* appeared in from one to three samples each. Crustacea were represented by *Bosmina* in six samples, *Cyclops* in three, *Daphnia* in one, and nauplius forms in six.

As might be expected, the spring plankton as a whole showed increase over the winter averages in practically every group of organisms, but the greatest effective growth was found in diatoms, green algae and flagellates. (Table 34.)

June, July, and August, 1922.—Summer samples, taken twice a week, numbered 25. Average yield of total plankton was 1,740 units, of which 1,078 units were known index organisms. These showed 19 per cent of pollution forms.

The total production of these summer samples was more than twice the yield of the spring samples. This hundred per cent increase was due in great measure to the fact that the green algae, already dominant in the spring samples, further increased by two and a half times, thus bringing the summer average of green algae up to 1,083 units, which is considerably higher than the average yield of total plankton during the spring. (See Table 34.) Another important group, the flagellates, increased from the spring average of 113 units to a summer average of 360 units. It seems obvious that the very slow movement of water through the mile-wide lake, together with adequate exposure to air and sunlight has proved a favorable environment for the growth of these chlorophyll-bearing organisms.

Diatoms were not abundant. *Synedra* appeared in two-thirds of the samples, but in small quantity. *Tabellaria* and *Navicula* were found in three or four samples each. The blue-green algae were moderately plentiful, increasing from an average of 13 units in spring samples to an average of 90 in the summer. *Merismopedia*, fragments of *Anabaena*, of *Oscillatoria*, and of *Nostoc* were the chief organisms present.

Of the green algae *Pleurococcus*, *Scenedesmus*, *Tetraspora*, and unidentified green cells were in practically every sample. *Actinastrium*, *Polyedrium*, *Celastrum*, and *Dictyosphaerium* appeared in more than half the samples, and *Staurostrum*, *Closterium*, *Raphidium*, *Pediastrum*, *Botryococcus*, *Gleocystis*, *Pandorina*, and *Volvox* less often.

The rhizopod *Diffugia* was found in a half dozen samples. Flagellates were an important group, as already stated. The leading genera were *Cryptomonas*, *Euglena viridis*, *Phacus*, *Trachelomonas*, *Chlamydomonas*, *Euglena oxyuris* and *Anthophysa*.

The ciliates as a group were not important and did not show the great relative increase exhibited by algae and flagellates. The spring average of 48 units increased to 76 units in the summer samples, an

advance of 58 per cent, whereas the summer plankton as a whole showed an advance of over 120 per cent over the spring yield. It is further significant that the cleaner-water form *Codonella* appeared in 17 of the 25 samples, whereas the pollutional forms were of less frequent occurrence, *Vorticella* in 16 samples; *Colpidium* in 12, *Carchesium* in 9, and *Epistylis* in 4. *Tintinnus*, the frequent cleaner-water companion of *Codonella*, was also found in seven samples.

Rotifers were present throughout the summer, but in small numbers. Several varieties of *Brachionus* were occasionally present, as was also *Polyarthra*, *Anurxa cochlearis*, *Asplanchna*, *Monostyla*, and *Rotifer tardus*, the last appearing in two samples only. Of the crustacea, *Cyclops* and naupleii were found in about half the samples, *Bosmina* in six, and *Daphnia* in two.

Summary.—The polluted stream moving with fairly rapid current encounters, at station 179, an expanded section which enables the water to spread over an area about a mile wide and 17 miles long. This is virtually a shallow reservoir, and though much of the water in the channel proper proceeds on its way through this lake, the stream passing, in fact, between banks of water, yet there is necessarily more or less mixing of channel water with the partly impounded water on either side. Every rise in levels will cause water to flow from the channel into these impounding areas, and every fall in levels will drain some of the water from these same areas. Even minor fluctuations resulting from the nightly flood of water from the drainage canal through the turbines of the power house at Lockport will contribute to the inevitable mixing, to some extent, of channel water with the adjacent impounded water through these liquid channel banks which function as limits for the channel water when levels are constant, as passageway to the impounding areas when levels are rising, and as drainageway back to the channel for mixed and impounded water when levels are falling.

The "Narrows," where station 166 was located, is nearly at the lower end of this lake. The water passing through this constricted portion is necessarily a mixture of original channel water and that which is drained, to a greater or less extent, from the adjacent impounding areas. Movement through the channel itself is very slight, thus greatly increasing the time period available for biological purification as the channel water passes through the lake. But the time period available for biological action in the impounded water must be very much greater. For this reason we are led to expect that samples from this station, the "Narrows," though only 13 miles below station 179 at the head of the lake, will show appreciable progress in the matter of biological purification.

Comparison of the monthly and seasonal summaries from these two stations show reasonable confirmation of this expectation.

Convenient data are found in the summaries for each season, in Tables 31 and 34. Here it will be noted: (1) Green algae at 166 exceed this same group at 179 in every season except one (spring, 1922); (2) Mastigophora or flagellates (practically all containing chlorophyll) exceed at the lower station except in winter (when the count is very low at both places). These facts would seem to indicate that the period of delay and quiet in the lake has enabled these better-water organisms to multiply to advantage. Meantime these chlorophyll-bearing organisms, each in its own minute parcel of water, have been producing oxygen, thereby contributing to the effective reduction of organic matter. (3) The ciliate content of the collections at stations 179 and 166 respectively, are, on the whole, significant as to the progress of purification during passage through the intervening lake. Reference to the table above mentioned shows that the average ciliate content at the lower station is very much less than at the upper station during 9 months of the 14 months' study. As a class the ciliates are usually indicative of sewage pollution, and these relative numbers at the entrance and exit, respectively, of the lake apparently testify to the progressive disposal of the organic matter. But the *kinds* of ciliates becomes a matter of importance here. Reference has already been made to the frequent appearance at station 179 of the cleaner-water ciliate *Codonella*, which was entirely absent from the collections of the heavily polluted upper river, and appeared first in occasional collections at Henry, 17 miles above station 179. An inspection of all the original plankton counts at the two stations under consideration (179 and 166) shows:

(a) In 116 collections at station 179 the ciliate content totaled 5,027 units, of which 752 units, or 15 per cent, were *Codonella* and the similar form *Tintinnus*. The remaining 85 per cent was made up of the pollutorial forms *Carchesium*, *Colpidium*, *Vorticella*, etc.

(b) In 113 collections during the same period at station 166 the ciliate content totaled 4,680 units, of which 2,054 units, or 44 per cent, were the cleaner-water forms *Codonella* and *Tintinnus*, and only 56 per cent were the distinctly pollutorial forms.

It thus seems plain that in the increasing prominence of certain cleaner-water forms among the ciliates themselves we have added evidence of the satisfactory progress of purification in the water as it slowly traverses the lake.

(4) Another item to be noted as an evidence of extensive and satisfactory purification effected during passage through the lake is the relative proportions at stations 179 and 166 of all the pollutorial and cleaner-water forms respectively, including the ciliates. The seasonal summary given in Table 6 affords convenient data for inspection, and the figures given include all plankton that have any known sanitary significance; that is, the "index organisms." It will be noted that,

while pollutional organisms made up 27 to 70 per cent (during the various seasons) of the known index organisms at the head of the lake, the collections at the lower end (station 166) show pollutional forms constituting only 19 to 31 per cent during the same period of time.

(5) It is noticeable that the plankton is showing an increasing number of forms or varieties. The rotifers may be cited as an example. Only one kind of rotifer was common in the upper river at La Salle and above. At Henry (station 196) half a dozen kinds were

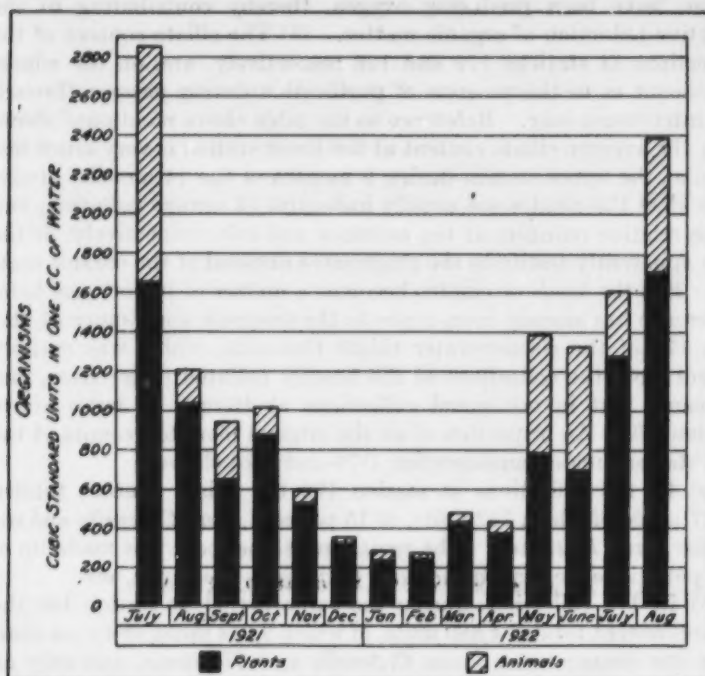


FIGURE 11.—Station 166. Monthly averages of weekly plankton catches expressed as plants and animals

noted, while at stations 179 and 166 the list has increased to a dozen or more. Variety of organisms seems to be the biological reflection of the presence in the water of the several varieties of food and of certain physical and chemical conditions which severally or collectively form those slightly differing conditions of environment required by these various members of any given group of organisms. It seems reasonable, therefore, that the logical explanation of the increasing variety of organisms lies in the fact that the organic matter (chiefly sewage) in the Illinois is being split up and separated into a large

number of by-products. In other words, visible sewage pollution is no longer a characteristic of the water, for the original pollution is now represented by a variety of derived substances which make possible the acceptable environment of the many different organisms that now constitute the varied plankton.

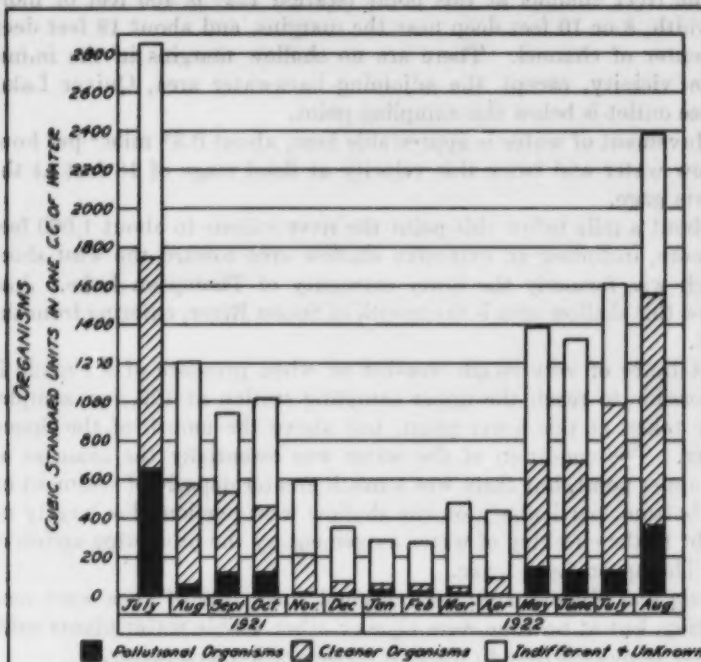


FIGURE 12.—Station 186. Monthly averages of weekly plankton catches expressed as pollutonal, cleaner, and indifferent

STATION 122. HAVANA

This station is 168 miles below the mouth of the Chicago Drainage Canal and 122 miles above the mouth of the Illinois.

About the only event of importance to the water as it passes from Peoria Lake at station 166 to Havana is the addition of sewage and industrial wastes at Peoria and Pekin, including certain wastes from the corn-products plant at the latter place.

The collecting station is about 2 miles above the bridge at Havana, sufficiently far to be well upstream from the mouth of Spoon River, opposite Havana, and from the partly impounded water of Quiver Lake, a backwater area covering a few hundred acres adjacent to the channel above the town. When sampling began Thompson Lake, a backwater area covering five or six thousand acres, was still open to

the channel, and the sampling point chosen was nearly a mile above the outlet of this body. Subsequent reclamation operations and the building of a levee separated this area from the river. About 25 miles upstream, "Pekin Lake" forms a shallow backwater area of about 3 acres, which is open at the lower end to the river channel.

The river channel at this point (station 122) is 400 feet or more in width, 8 or 10 feet deep near the margins, and about 18 feet deep in center of channel. There are no shallow margins in the immediate vicinity, except the adjoining backwater area, Quiver Lake, whose outlet is below this sampling point.

Movement of water is appreciable here, about 0.37 mile² per hour at low water and twice this velocity at flood stage of 18 feet at the Peoria gage.

About a mile below this point the river widens to about 1,000 feet or more, including an extensive shallow area toward the west shore which was formerly the lower extremity of Thompson Lake. Just below this shallow area is the mouth of Spoon River, entering from the west.

At times of very rough weather or when presence of ice made it impossible to reach the upper sampling station at 122, our samples were taken at this lower point, but above the mouth of the Spoon River. The condition of the water was essentially the same as at the upper point, but there was a much greater deposit of sediment on the bottom, particularly on the shallow west portion, due largely no doubt to the checking of water movement by the protecting action of the Thompson Lake levee.

July and August, 1921.—Occasional small bits of algæ were seen floating, but at no time were algæ or other visible water plants sufficiently numerous here to warrant consideration as a factor.

The bottom here is rather firm as compared with the great mass of soft spongy mud at station 179. The mud obtained in July was dark, somewhat stiff and claylike, with very slight odor, and contained very few organisms of any kind. The three 1-liter samples yielded 1 tubificid worm, 1 chironomus larva, and 5 leeches. Rather large numbers of snail shells were found at east and center, but no living snails. One young living bivalve was found. Rather large amounts of plant detritus, leaves, and sticks blackened and partly decayed, were conspicuous in the west sample.

In late August water was nearly clear with no algæ or surface film visible. Mud samples showed slight odor, were dark in color, and contained very few organisms, but large amounts of plant detritus. Organisms in the three 1-liter samples averaged 14 tubificid worms, 9 chironomus larvæ, chiefly *C. lobiferus*, and *C. digitatus*, 3 caddis

¹ Richardson, in Bull. Nat. History Survey, Vol. XIII, Art. XV, p. 377.

larvae (Hydropsyche) and an occasional leech and bivalve. Many snail shells were present, but no living snails were found. (See Table 35.)

TABLE No. 35.—Bottom sediments

STATION 123 (HAVANA)

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms
	At station 123, just above Havana, the river is about 400 feet wide, with clean, wooded shores and no shallow margins except below and some miles above this point. The current is brisk, and water-bloom, algae, etc., are rarely in evidence. A small amount of Arum, on the east shore is the only aquatic plant of consequence. Floatage was rarely seen during our 13 trips of inspection. There is no odor and the water looks clean. Since surface and margins appear always to be relatively clean and without fluctuating factors so noticeable in the upper, heavily polluted portions, the following data will be mainly confined to a consideration of the bottom sediments unless otherwise stated.
1921	
June 9	(1) Bottom sediment from west side of channel. Somewhat granular, with very slight odor. Contained plant detritus. (2) One liter of sediment yielded few tubificids (11), an occasional minute mussel, Chironomid larva, leech, crustacean (<i>Leptodora</i>), and a small amount of the bryozoan <i>Fabudicella</i> .
July 26	(1) Three samples (from east, center, and west, respectively) were dark, somewhat sticky, with slight odor, and contained plant detritus. (2) Very few organisms, the three 1-liter samples yielding only 1 tubificid worm, 1 chironomid larva, and 5 leeches. Shells of snails were present, but no living snails.
Aug. 27	(1) Three samples show dark, rather tough mud, with slight odor and large amount of plant detritus. (2) Average of the three 1-liter samples indicates few tubificids (16), chironomid larvae (<i>C. lobiferus</i> 3, <i>C. tentans</i> 1, <i>C. digitatus</i> 2), caddis larvae (<i>Hydropsyche</i> 3, <i>Polycentropus</i> 1), leeches 2, young bivalves 2, an occasional <i>Ancylus</i> , and a single specimen of the crustacean <i>Hirysella</i> .
Sept. 29	(1) Dark, without special odor other than an "earthy" odor. Moderate amount of plant detritus. (2) Two samples average very few tubificids (26) and an occasional leech, and larvae of chironomus and caddis. No living snails.
Nov. 1	(1) Gray-black, soft, with slight odor. Moderate amount of plant detritus and broken shells of snails and bivalves. (2) Three 1-liter samples average 1 tubificid worm, few chironomid larvae (<i>C. lobiferus</i> 4), caddis (<i>Hydropsyche</i> 4), and an occasional planarian, leech, dragonfly larva, and bivalve. Moderate numbers (21) of empty snail shells and a few of <i>Ancylus</i> .
Dec.	
1922	No bottom samples could be obtained on account of ice and rough weather.
Jan.	
Feb.	
Mar. 8	(1) Dark, tough to granular, with slight odor. Moderate amount of plant detritus. (2) Three samples average 44 tubificids, 3 chironomids, and an occasional living snail, bivalve, and leech.
Apr. 6	(1) Dark, somewhat tough, with slight odor. Contained large amount of minute detritus of plants. (2) Three samples average 63 tubificids, 3 minute bivalves, 2 chironomid larvae, and an occasional snail, leech, and larva of caddis (<i>Hydropsyche</i>). Shells of snails were abundant.
May 16	(1) Dark, tough, with slight odor, and containing a large amount of plant detritus. ¹ (2) Three samples average 84 tubificids, 28 chironomid larvae (<i>C. flavus</i> 10, <i>C. digitatus</i> 5, <i>Tanytus monilla</i> 1, unidentified 7), and 2 or 3 bivalves. Small amounts of <i>Urnatella</i> attached to empty snail shells. Cases of caddis larvae and a few pots of <i>Hydropsyche</i> were found.
June 22	(1) Dark, sticky, but granular in places. With slight odor. Large amount of plant detritus. (2) Three samples average 78 tubificids, 4 or 5 bivalves, 3 chironomid larvae (<i>C. digitatus</i>) and an occasional larva of Odonata.
Aug. 8	(1) Dark, tough, but slightly granular, with slight odor. Small amount gas released from bottom by sampler at center and west points. Plant detritus in moderate amount. (2) Three samples averaged 35 tubificids, 1 each of chironomid larva (<i>C. digitatus</i>) and caddis larva. Empty shells of snail, bivalve, and <i>Ancylus</i> moderately abundant.
Aug. 24	(1) Dark, slightly granular, with slight odor. Contains moderate amount detritus from plants and shells. (2) Three samples average 57 tubificids, 28 Chironomid larvae (<i>C. lobiferus</i> 22, <i>C. digitatus</i> 4, <i>Procladius culiciformis</i> 4, <i>Procladius carnosus</i> 3, <i>Procladius concinnus</i> 2, others 2), caddis larvae 5 (<i>Hydropsyche</i>), an occasional bivalve, and small amounts of bryozoa. Empty shells of snails, bivalves, and <i>Ancylus</i> were moderately abundant.

¹ During strenuous efforts, in April, to prevent the breaking of the newly constructed Thompson Lake Levee, about three-fourths mile upstream, cornstalks, etc., were used in large quantities. It is possible that some of the plant detritus found in the bottom sediments is from this source.

The summer plankton, 1921.—Samples were collected weekly. During these summer months the 12 samples averaged a total plankton content per cubic centimeter of 1,760 cubic standard units, of which 954 units were index organisms. These latter averaged 46 per cent pollution forms and 54 per cent cleaner-water forms. (See Tables 36 and 37.)

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TABLE NO. 36.—Classification of plankton organisms
STATION 122 (HAVANA), MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates ¹	Rotifers	Crustaceans	Spores, etc.	
1931											
June.....	163	137	685		10	263	196	3	379	33	.....
July.....	35	665	731			153	3	173	135	35	.....
August.....	32	440	708	85	1	134	167	96	96	30	.....
September.....	31	64	405			163	190			5	.....
October.....	135	166	545	11	1	80	3			1	.....
November.....	264	6	440	5	3	58	4	13		9	.....
December.....	68	13	345			15	1	11		16	.....
1932											
January.....	10	3	161			6	19				12
February.....	40	10	330			5	33				36
March.....	90	3	515			36	29	13			36
April.....	164	10	397	10		16			10		40
May.....	347	49	696	6		268	80	7	34		15
June.....	166	135	661	11	38	430	55	19	190	30	.....
July.....	130	280	1,403	5		416	36	34	11	90	.....
August.....	71	557	1,505		11	581	130	100	84	34	.....
Averages:											
Summer.....	66	465	689	19	3	170	80	90	180	33	1,764
Autumn.....	146	54	490	6	1	80	80	5		10	823
Winter.....	40	3	265			5	17	4		31	353
Spring.....	337	16	553	5		130	33	6	18	31	1,132
Summer.....	119	341	1,310	5	10	463	73	80	64	44	3,480

¹ In all collections taken at 122, pollutional ciliates=1,397 units (31 per cent) and cleaner-water ciliates=1,557 units (46 per cent).

TABLE NO. 37.—Summary of plankton findings for all months
AVERAGES AT STATION 122, HAVANA

Date	Plankton catch, cubic standard units in 1 c. c. of water									
	Total catch			Total organisms				Total organisms		
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms	Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi		
1931										
June.....	767	663	1,390	60,000	767	263	551	6	196	473
July.....	1,469	469	1,938	75,100	1,469	147	323	0	655	511
August.....	1,265	668	1,733	65,000	1,340	134	333	45	467	376
September.....	494	330	823	55,000	494	163	195	0	126	343
October.....	890	180	1,070	25,000	790	80	20	11	79	374
November.....	665	80	745	25,000	662	53	27	6	16	186
December.....	430	43	463	16,100	430	15	27	0	13	82
1932										
January.....	181	30	219	10,000	181	6	32	0	19	10
February.....	400	73	473	35,000	400	4	90	0	33	14
March.....	614	104	718	35,100	614	26	78	0	26	41
April.....	714	65	779	45,000	704	16	49	10	0	49
May.....	1,530	330	1,863	15,000	1,534	260	137	6	90	693
June.....	1,311	664	1,975	25,300	1,301	430	335	11	113	802
July.....	1,307	305	1,612	60,100	1,303	413	185	5	261	1,048
August.....	2,133	559	2,694	31,900	2,133	327	323	0	565	1,048
Averages for 11 months.....	663	208	1,151	31,900	677	146	130	6	137	354

The list of specific organisms shows that in the light diatom content *Synedra* was the leading genus. Blue-green algae were moderately abundant, the chief kinds being *Merismopedia*, fragments of *Oscillatoria*, and the very minute blue-green resembling fragments of *Beggiatoa* (see p. 117). The green algae *Pleurococcus*, *Scenedesmus*, and minute green cells (unidentified) were in 8 of the 12 samples, and *Calostrum*, *Actinastrum*, *Tetraspora*, *Raphidium*, and *Pandorina* in 3 to 5 samples each. The flagellates were practically all chlorophyll-bearing, *Cryptomonas*, *Chlamydomonas*, *Euglena viridis*, and *Trachelomonas* being the leading ones. Ciliates were represented by the cleaner-water form *Codonella* in 7 samples, and the pollutional forms *Vorticella*, *Colpidium*, and *Carchesium*, in 5, 3, and 2 samples, respectively. *Paramacium* and *Epistylis* appeared in a single sample each. *Brachionus pala*, *B. doreas*, *B. rubens*, and *Polysartha* were the leading rotifers, but these were not abundant, though a considerable variety was in evidence. Crustacea were relatively abundant, *Cyclops* appearing in 8 samples and naupleii in 10, with *Bosmina* and *Chydorus* in 1 sample each.

A noticeable characteristic of this summer plankton is the variety. Every class is represented whereas at the upper river stations in the Joliet region rotifers were represented usually by one kind only, and rhizopods and crustacea were absent most of the time.

September, October, and November, 1921.—In late September the water looked clean, except for slight turbidity. There was no odor. No mud sample could be obtained at center on account of very rough water, the result of wind. East and west samples of mud were dark in color, without special odor, and contained moderate amounts of plant detritus. Organisms present were about 50 tubificid worms (in west sample only) and a few leeches, with an occasional chironomus larva and caddis larva. No living snails were found, though shells were plentiful. In late October and early November the three mud samples yielded four tubificid worms, a dozen chironomus larvae (*C. lobiferus*, chiefly), nine caddis larvae (*Hydropsyche*), and an occasional leech, planarian, and dragon-fly larva. One living mussel was found. Shells of snails and of *Ancylus* were moderately abundant.

The autumn plankton.—The 12 samples averaged about 830 cubic standard units of total plankton. Index organisms made up 341 units of this average, 21 per cent being pollutional forms.

Diatoms increased somewhat over the summer content. *Synedra* was found in most of the samples, *Tabellaria flocculosa*, *Asterionella*, and *Fragilaria* in four or five samples. Blue-green algae were not abundant, being present in small amount in only five or six samples. A considerable variety of green algae, in moderate total amount, was noted in these autumn samples, the list including *Pleurococcus*, *Tetraspora*, *Scenedesmus*, *Actinastrum*, *Calostrum*, *Raphidium*, and *Botry-*

cooccus. All flagellates found were chlorophyll-bearing. *Cryptomonas*, in eight samples, was the most abundant. *Chlamydomonas* and *Trachelomonas* each appeared in five samples, and *Euglena viridis* in three. Ciliates were not abundant, but were present in nearly every sample, *Codonella*, the cleaner-water form being in six samples, the pollutional form *Vorticella* in six, and *Carchesium* in three. Rotifers were all but absent, *Anuraea cochlearis* appearing in two samples, and *Brachionus pala* in two. Crustacea were not found.

December, 1921, January, and February, 1922.—In December rough weather at the time of our visit prevented the obtaining of mud samples. In January ice prevented access to the sampling points. No further field trip was attempted until early March, data of which will properly appear in subsequent pages.

In January the ice did not cover the entire river. The channel proper was free, but ice was prevalent along both margins and out 50 feet or more toward the channel, sealing up the rowboats and other small craft unless by some larger vessel or other means a pathway was broken to the open water. The water looked clean, was free of floatage, and without odor.

The winter plankton.—The 12 samples yielded an average total plankton of 385 cubic standard units, of which only 47 units were known index organisms, these being 46 per cent pollution forms. (Table 6.)

Asterionella and *Synedra* were the leading diatoms. Blue-green algae were only occasionally present, and in very small amount. Green algae, in very moderate quantity only, was made up chiefly of *Pleurococcus*, unknown green cells, and a very few each of *Scenedesmus*, *Tetraspora*, *Celastrum*, and *Raphidium*. A very few flagellates (*Cryptomonas* and an occasional *Euglena*) appeared in these winter samples. Ciliates appeared in some variety, but in small total quantity. The pollutional *Colpidium* was most abundant, appearing in five samples. Similar pollutional organisms, *Vorticella*, *Epiplatys*, and *Carchesium*, were found in three samples, or less often. The cleaner-water *Codonella* appeared in but one sample. Rotifers were few, *R. tardus*, *Brachionus*, and *Euchlanis* appearing in a single sample each. No crustacea were found. (Table 36.)

March, April, and May, 1922.—In early March water was slightly turbid, with no floatage and no odor. Samples were taken at the lower of the two sampling points, below the Thompson Lake area but above the mouth of the Spoon River. This was approximately mile 121, or 1 mile below the regular sampling point.

Sediments were more abundant here than at the upper sampling point. Mud was dark colored, tough to granular rather than soft, had very slight odor, contained moderate amounts of plant detritus, and some organisms. These latter were chiefly tubificid worms, the

three 1-liter samples averaging 45 worms each. They were slightly more abundant in the west sample, where mud was present in large quantity. A very few chironomus larvae (*C. digitatus* and *C. lobiferus*), an occasional snail, bivalve, and leech completed the list.

In early April mud samples were again taken at this lower sampling point (121). The water was turbid and very high on account of continuous rains.

Mud samples were dark in color, somewhat tough, except at west, where mud was soft and spongy, had slight odor, and contained a large amount of minute plant detritus. Tubificid worms in small numbers appeared in all samples, 28, 96, and 64 in 1-liter samples taken at east, center, and west, respectively. A half-dozen small bivalves, 1 each of snail, leech, and caddis larva (*Hydropsyche*) and 5 or 6 chironomus larvae (*Procladius coccineus*) completed the catch from the three samples.

Very similar data resulted from a visit in mid-May. Water was still high and slightly turbid. Mud was dark in color, slightly tough, and with no special odor. Large amounts of plant detritus were present, and moderate numbers of tubificid worms, averaging about 75 per liter of mud and being most abundant in the west sample. In the total of about 60 chironomus larvae, there were identified 28 of *C. flavus*, 15 of *C. digitatus*, and 3 of *Tanytus monilis*. About half a dozen living mussels (*Sphaeriidae*) and one of larger size, unidentified, were found. Snail shells were abundant, and the bryozoan *Urnatella* was found growing on several of them. Shells of *Ancylus*, nests of *Hydropsyche*, and cases of caddis larvae were found in small numbers in these mud samples. (Table 35.)

The spring plankton.—Fourteen samples were taken during the three months. The average yield of total plankton was 1,120 units, 92 per cent of these being those chlorophyll-bearing organisms that produce excess oxygen. The average content of index organisms was 296 units, these being 12 per cent pollutional and 88 per cent cleaner-water forms.

The leading diatoms were *Asterionella*, in nearly every sample, *Synedra* in more than half, and *Navicula*, *Tabellaria flocculosa*, *Fragilaria*, and *Melosira* in three to five samples. The peak of diatom production came in May, the average content being 847 units as compared with an average of 164 units in April and 99 units in March. Blue-green algae were negligible in quantity, averaging only 18 units in these spring collections. Green algae were moderately abundant throughout the three months. There was only a slight increase in May. The leading kinds were *Pleurococcus* and minute unknown cells in practically every sample, *Tetraspora* and *Scenedesmus* in five or six samples and *Raphidium*, *Calastrum*, and a few others

appearing occasionally. Flagellates were present in moderate amounts, a material increase developing in May. *Cryptomonas* was the most abundant, but *Trachelomonas*, *Euglena viridis* and *Chlamydomonas* were occasionally present. The ciliate population was rather small, *Codonella* in 6 samples, *Colpidium* in 5, *Vorticella* and *Carchesium* each in 4, and *Epistylis* in 2, all of them averaging a ciliate content of 32 units. The few rotifers present occasionally were *Polyarthra*, *Asplanchna*, *Euchlanis*, *Brachionus urceolaris*, and *B. angularis*; all these appeared in a single sample each. Crustacea were sparingly present, usually in nauplius form, but mature *Cyclops* and *Boesmina* were found in a single sample each.

June, July, and August, 1932.—In latter June the water showed no floatage, no algae, no surface skum, was without odor, and in general had a clean appearance, except for very slight turbidity.

Mud samples were dark, sticky to granular, with slight odor, and contained large amounts of plant detritus. Organisms consisted of relatively small numbers of tubificidæ (about 75 per liter of mud) a very few mussels (*Sphaeriidæ*), a single dragon-fly nymph, and less than a dozen chironomus larvæ, practically all being *C. digitatus*.

The situation in late July was essentially the same as in June. The river had every appearance of the average clean stream, except for slight turbidity. Mud samples, however, were dark, varied from soft to tough, and had slight odor. A small amount of gas was released from the mud at center and west when the sampler was in contact with bottom. This is the first time in our sampling that any gas was observed at this collecting station.

Small numbers of tubificid worms (about 33 per liter), an occasional chironomus larva and a very few caddis larvæ made up the organism content of these mud samples. Shells of bivalves (*Sphaeriidæ*) and of snails were abundant but none of the living organisms were found.

In late August our final visit found the water looking clean, with the exception of slight turbidity. There was no floatage, no film, no odor. Water was rather low, necessitating use of a rowboat in the shallow area of the west sampling point. Mud samples were dark, slightly granular at east and center, rather soft at west, and showed a slight odor. There were moderate amounts of detritus from plants and from broken shells of snails and bivalves. Tubificid worms numbered 0, 112, and 145 at east, center, and west, respectively. Chironomus larvæ were rather numerous at east, the liter sample of mud yielding over 70 larvæ, 61 of which were *C. lobiferus*, 11 were *C. digitatus*, and 1 was a species of *Tanypus*. The center sample yielded a dozen larvæ, half of which were *C. digitatus*. The others were not positively identified. The west sample yielded 35 larvæ, as follows: *Procladius concinnus* 13, *Procladius cornutus* 9, *Procladius concinnus* 9, *Tanypus* 2, and 2 unidentified. Cases of caddis larvæ were numer-

ous at east, occasional at center, and none at all at west. Similarly the caddis larvæ *Hydropsyche* were found in moderate numbers at east, but none at center and west. Three young bivalves (*Unionidæ*) were taken in the east sample, and a large number of shells of snail, but no living snails were found.

The summer plankton, 1922.—The 13 collections yielded an average total plankton of 2,480 units. Of this total the index organisms averaged 1,516 units, 21 per cent pollutional and 79 per cent cleaner-water forms. As to oxygen-producing organisms, these made up 90 per cent of the total.

An inspection of the make-up of this summer plankton as shown in the group summary (Table No. 36) indicates that in comparison with the spring plankton the chief increase is in the blue-green algæ, the green algæ, and the flagellates, these three groups accounting for about 90 per cent of the 100 per cent advance shown by the summer plankton over that of the spring. Practically all groups however showed some increase in the summer yield except the diatoms, these dropping from 337 units in the spring to 119 units in summer. Diatoms present in the summer catches were *Synedra* in all samples, and *Navicula*, *Asterionella*, *Tabellaria*, and *Pleurosigma* in a very few samples. Of the blue-green algæ, the minute unidentified beeggiatoa-like filament appeared in 10 samples, *Merismopedia* in 8, *Anabaena* and *Oscillatoria* each in 4 and *Nostoc* in 3. The green algæ were abundant, and presented considerable variety—minute cells, *Pleurococcus*, *Tetraspora*, *Scenedesmus*, *Calanistrum*, and *Raphidium* being in practically all samples, and *Pediastrum*, *Dictyosphaerium*, *Closterium*, *Polyedrium*, *Pandorina*, *Gonium*, and *Kirchneriella* appearing occasionally. Flagellates were moderately abundant. *Cryptomonas* appeared in all samples, and *Euglena oxyuris*, *Chlamydomonas*, and *Trachelomonas* in about half of them. *Euglena viridis* and *Phacus* were frequently present. Of the ciliates, the one most frequently found was *Vorticella*, in 10 samples. The cleaner-water form *Codonella* appeared in eight, and the pollutional forms *Colpidium* and *Carchesium* in seven each. Rotifers showed a wide variety, but very few of any one kind. *Brachionus pala*, in six samples, was the most frequent variety. The following appeared in small numbers in two or three samples each: *Brachionus rubens*, *Polyarthra*, *B. angularis*, *Euchlanis*, and *Asplanchna*. Eggs of rotifers were occasionally found, and adults of *Triarthra*, *Mastigocerca*, and *B. urceolaris* appeared in one sample each. Crustacea were represented by *Cyclops* and *Bosmina* in three samples each, and by nauplius forms in seven samples.

Summary and discussion.—Biological investigations were carried on at Havana for 15 months, resulting in 62 plankton samples, 31 1-liter collections of bottom sediments with their contained popula-

tion, a few samples of algæ (4) and notes and observations as the result of 13 field trips to this station.

The plankton.—As noted in a previous paragraph, the chief events of importance after the water leaves Peoria Lake at station 166 consist of the addition of untreated sewage at Peoria and Pekin, whose combined sewered population is 76,700 and the further acquisition of wastes from the various industrial plants in both cities aggregating the equivalent of an additional population of 652,500. This includes the corn-products plant at Pekin. The greater part of the wastes of this plant are discharged into an artificial lake of about 3 acres area, where it undergoes some digestion, presumably by chemical and biological action, before it finally reaches the river by slow, but continuous discharge of the lake contents through an outlet at the extreme lower end. Evidence of great biological activity in this lake is furnished by a plankton sample taken in June, 1922. The plankton content was very heavy, over 13,000³ cubic standard units, or 104 parts per million, by volume of organisms in 1 cubic centimeter of water. The chief groups were blue-green algæ, green algæ, and rotifers. Diatoms were absent. Flagellates appeared only in very small numbers. Ciliates were even less numerous. The three groups first named made up 29, 53, and 13 per cent, respectively, of the total plankton, or the three combined constituted 95 per cent of the total yield.

It seems reasonable that because of the very heavy plankton content the continuous discharge of even a small stream from this lake may produce a noticeable result in the plankton content of the river. This effect on the river would be more noticeable in case any of the large groups of this lake plankton differed essentially from the organisms commonly found in the river.

Reference has already been made to the occasional presence, in the upper river of a minute blue-green alga whose general appearance resembled that of *Beggiatoa*, the sulphur bacterium. This blue-green was very abundant in this small lake at Pekin and was the only blue-green found in the plankton. Reference to the figures already given will show that it numbered about 3,800 units, constituting in itself a heavy plankton. Relatively large counts of this minute alga were found not only in the Havana samples only 25 miles downstream, but also at station 100, just above the mouth of the Sangamon, and finally as far down as Kampsville (station 25). The seeming improbability of this organism from Pekin appearing in noticeable quantity in the river samples 45 miles and even 120 miles downstream will be lessened materially when it is stated that the algæ is very light,⁴ the greater

³ The heaviest plankton taken in the river proper during the 14 months' investigation was about 6,300 units at Havana, Aug. 11, 1922.

⁴ Owing to the unusual specific gravity of this organism, it would seem impossible to use the centrifuge method of concentrating plankton samples in any water which contained this alga in appreciable amount.

portion by far floating at the surface, and in the plankton catch forming a heavy surface coating. In the counting cell the minute filaments gravitated upward and were found immediately beneath the cover glass instead of at the bottom of the cell. It is likely, however, that the alga continues to increase somewhat as it is carried downstream. Moreover, the polluted Sangamon River, joining the Illinois just below station 100, contains moderately large amounts of this same organism, and these contributions will doubtless figure in the plankton content of the river at station 25 perhaps quite as much as does the very heavy yield in the small outlet from the lake at Pekin. But at no point in the river does this minute alga approach the very heavy growth that is found in the small lake at Pekin which receives the wastes from the corn-products plant.

The plankton peak.—According to our records plankton production of the Illinois River reaches its peak at Havana. The average yield of all samples taken at this point, 62 in number, is 1,281 cubic standard units per cubic centimeter of water. (This is about 10 parts per million by volume.) The average yield in the turbulent upper river at Joliet is 637 units. About midway in the river's course, at station 179, the average total yield is 879 units. Passage through Peoria Lake apparently tends to increase production, for the average at station 166 is 1,089 units. After a flow of about 46 miles, receiving meantime the sewage of Peoria and of Pekin, the plankton yield at Havana reaches, as stated, an average of 1,281 units. Twenty-two miles farther downstream, at point 100, collections taken over a period of six months (June to November) averaged 1,031 units, and at the final sampling point, only 25 miles above the river's mouth, the weekly collections over a period of 14 months averaged 1,087 units, practically the same as the average yield at the outlet of Peoria Lake at station 166 during the same period.

The peak production at Havana is due chiefly to very high yield in the summer months, which brings up the average when all samples are included. If the winter months alone be considered, the peak production for this season (December, January, February, March) is found to be 807 units at station 25. The winter average at Havana is only 468 units.

The heavy plankton yield at Havana is further due in part to the relatively heavy increase of pollutorial organisms, due apparently to the addition of fresh sewage and other wastes from Peoria and Pekin. During a period of 14 months, the average of all collections at station 166, just above Peoria, when placed on an 11 months' basis compares as follows with the average of all collections at Havana during the same 14 months' period similarly placed on 11 months' basis: (Values are stated in cubic standard units.) (See Table 5.)

Station	Pollutional organisms	Cleaner-water organisms	Indifferent and unknown	Total plankton
166.....	96 (11 per cent of total).	330 (36 per cent of total).	607 (67 per cent of total).	994
Havana.....	127 (11 per cent of total).	354 (31 per cent of total).	610 (56 per cent of total).	1,181
Increase at Havana over station 166 (units).	29.....	18.....	173.....	317
Increase at Havana over station 166 (per cent).	29.....	4.....	28.....	23

It will be noted, in last line above, that the per cent of increase of pollutional organisms at Havana was more than seven times as great as was the per cent of increase in cleaner-water organisms. In fact these latter forms, increasing by only 4 per cent, did not keep pace with the general increase of 23 per cent shown by the total plankton. It thus seems obvious that the advent of sewage and wastes from Peoria and Pekin not only increased the relative content of pollutional organisms in the plankton, but meantime also inhibited to some extent the normal multiplication of the cleaner-water forms.

Looking at the preceding tabulation from another angle, it is to be noted that the total plankton at station 166 is made up of 11 per cent pollutional forms, 36 per cent cleaner forms, and 53 per cent of "indifferent and unknown." At Havana this make-up of the total has been unchanged by the per cent of pollutional organisms, but decrease of the per cent of cleaner forms has occurred, and slight change, is shown in those forms which are known to be relatively indifferent to sewage, or whose response to such conditions, if any, is unknown.

The bottom sediments.—Prevailing physical characteristics of these sediments indicate that decomposable matter is present in moderate amounts only. (Table 35.) The situation will be better understood by comparing the sediments with those collected above Peoria at station 179. (Table 30.) (No sediments could be collected in the swift water at station 166.) The sediments at 179 were black, very soft, spongy with gas, and had a strong disagreeable odor. The sediments at Havana were usually black, but were somewhat firm, tough, or granular, showed traces of gas only occasionally, and had very slight odor, or none.

In keeping with these differing physical conditions and with the differing amounts of organic matter which they seem to indicate, the populations of these sediments at 179 and at Havana differ in a typical fashion. The average population of a liter of mud at station 179 consists of approximately 2,200 sludge worms, 460 bivalves of the tolerant *Sphaeriidae*, an occasional snail, a dozen chironomus larvae, and 1 leech. At Havana the average yield during the same period of time is only 46 sludge worms, 1 bivalve, an occasional snail,

9 chironomus larvæ, and 1 leech. There were also present at various times small numbers of caddis larvæ, dragon-fly larvæ, planarians, crustacea, and bryozoa. All these latter were entirely absent from the mud samples taken at 179.

The great decrease in sludge worms (which, when in large numbers, are typical of heavy pollution), together with the large increase in variety of organisms found at Havana over those at station 179, constitute evidence of substantial improvement in the bottom sedi-

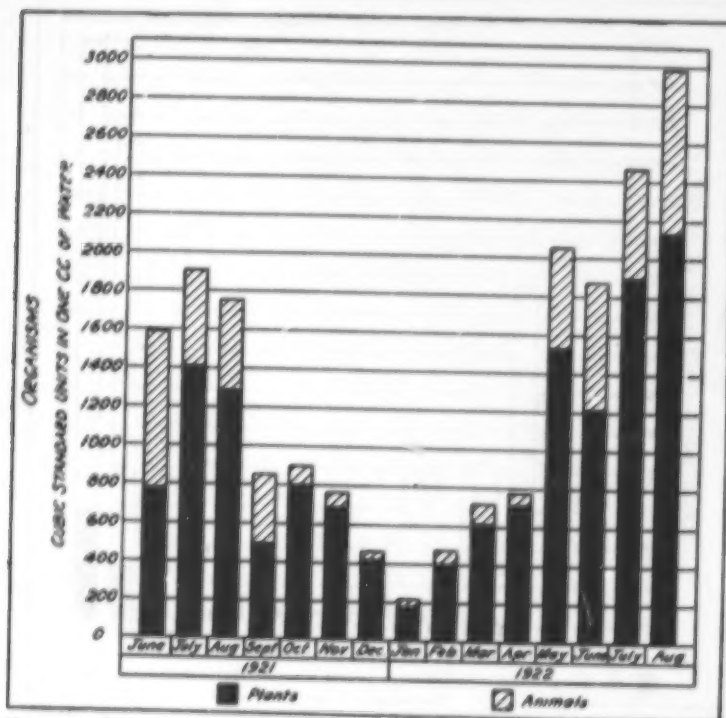


FIGURE 13.—Station 122. Monthly average of weekly plankton catches expressed as plants and animals

ments. It seems probable that the sewage of Peoria and Pekin, though sufficient to affect the character of the plankton, is meanwhile unable to produce any appreciable change in the more stable sediments at the river's bottom.

It is further to be noted that, in the plankton, cleaner-water organisms outnumber pollutional forms nearly 3 to 1 at Havana (see tabulation, p. 142), even after the temporary increase of the latter due to Peoria sewage. It thus seems probable that biological purification is progressing satisfactorily, and that the relatively clean Spoon

River, joining the Illinois at Havana, will assist, rather than hinder, the further improvement of the stream as the water proceeds toward the lower reaches.

THE SPOON RIVER

The drainage area of the Spoon comprises 1,870 square miles of low-lying farm lands, prairie, and low hills. Consistent with this type of watershed, the fluctuations of this river are gradual, the water

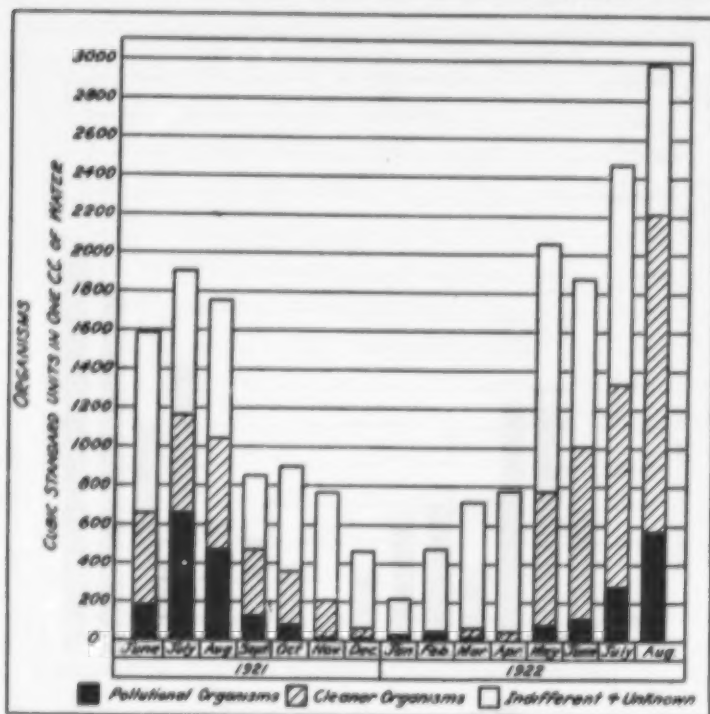


FIGURE 14.—Station 122. Monthly averages of weekly plankton catches expressed as pollutinal, cleaner, and indifferent

rising slowly, and the flood receding in like manner. At low water the current is somewhat sluggish, and even when the stream is bank full the current can hardly be termed brisk. The lower reaches of the stream are crooked and tortuous with wide curves, and the channel, about 80 feet wide, is lined on each side with a heavy growth of small timber, much of which is gracefully draped with vines along the low banks where sunlight is abundant. No emergent plants were found in this lower wooded portion of the stream, and the water seemed free of filamentous algae.

The current is not sufficient to carry out all the suspended matter. There is an extensive deposit of mud over practically all the bottom. This mud is exceedingly soft, much of it being about semiliquid in consistency, like very thin mortar. There seems to be nothing of a granular nature in it. On the contrary it is uncommonly smooth, like thin cornstarch, and the ultimate particles of which it is composed are microscopic in size.

At times of slight rise and even slight increase in speed of current the water of the Spoon becomes very turbid. It seems obvious that most of this turbidity is from this very thin, light mud which covers the bottom. The suspended matter in this turbid water is so fine and light that a bottle of such water will not clear up for more than a week.

The watershed of the Spoon contains no large towns. There is neither sewage nor industrial waste discharged into its waters in any considerable amount. The stream is relatively unpolluted and will therefore serve to diminish, rather than to increase, the degree of pollution of the Illinois River into which it flows at Havana.

TABLE NO. 38.—*Bottom sediments*

STATION, SPOON RIVER

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms
1921	
June 9...	(1) Brownish, very thin, r- th , and livery. No odor. Practically no detritus. (2) Tubificid worms 7, young bivalves... Chironomid larvae: <i>Procladius californicus</i> 1, <i>Tanytus</i> 1, May-fly larva (<i>Hexagenia</i>) 1.
July 26...	(1) Nearly black, very soft and livery. No odor, no detritus. (2) Tubificid worms 7, larvae of <i>Hexagenia</i> 12, of <i>Tanytus monilis</i> 2, of <i>Tanytus</i> , sp. A, 1. Very young bivalves 2.
Aug. 27...	(1) Nearly black, but brown on surface. Soft and thin. No special odor. (2) Tubificid worms 8, larvae of <i>Hexagenia</i> 12, of <i>Chironomus</i> (<i>Tanytus</i> sp.) 4. Young bivalves 5.
Sept. 29...	(1) Nearly black. Very soft. Odor slight or none. Moderate amount of plant detritus. (2) Tubificid worms 9, larvae of <i>Hexagenia</i> 7, of <i>Chironomus</i> (<i>C. digitatus</i>) 1, <i>Ceratopogon</i> larvae 1, young bivalves 2.
Nov. 1...	(1) Grayish. Very soft and smooth. No odor. Small amount detritus. (2) Tubificid worms 12, <i>Chironomus</i> larvae (<i>C. digitatus</i>) 1, young mussels 2.
Dec. 2...	(1) Dark, very soft, no odor. Much plant detritus, chiefly leaves. (2) Tubificidae 7, larvae of <i>Hexagenia</i> 5, <i>Chironomus</i> (<i>Tanytus</i>) 1, <i>Corethra</i> larvae 1.
1922	
January...	River frozen over. No sample obtainable.
February...	No trip to this station.
Mar. 8...	(1) Gray-black, very soft, smooth, and soupy. Practically no odor. (2) Tubificid worms 20, larvae of May fly (<i>Hexagenia</i>) 1, and of stone fly (<i>Plecoptera</i>) 1.
Apr. 8...	(1) Yellowish, very soft, and smooth. Slight odor or none. (2) Tubificid worms 4. No other organisms found.
May 16...	(1) Yellowish, very soft, and semiliquid. No odor. (2) Tubificid worms 4, naid worms (<i>Chaetogaster</i>) 3. No other organisms present.
June 23...	(1) Brownish. Very soft, smooth, and thin. Practically no odor. (2) Tubificid worms 8. No other organisms present.
Aug. 5...	(1) Yellowish, very soft. No odor. Large amount fine plant detritus. (2) Tubificid worms 9. No other organisms present.
Aug. 24...	(1) Somewhat dark. Very soft and smooth. Odor slight or none. Small amount of plant detritus. (2) No tubificid worms. <i>Chironomus</i> larvae (<i>Tanytus monilis</i>) 7, unidentified 7. Young bivalves 1.

June, July, and August, 1921.—In early June the water was very turbid, though free of floatage and debris. No algæ or aquatic plants, submerged or emergent, were in evidence. The environment seems unfavorable for aquatic plants, for trees lining both banks shut out much of the light and the stream channel is several feet

deep from bank to bank. There are no shallow margins to encourage plant growth in this lower, shaded portion of the Spoon.

In late July water bloom, composed chiefly of the flagellates *Trachelomonas* and *Chlamydomonas*, was abundant on the quiet surface. A few bubbles were visible, but no septic action was apparent as a possible source of these bubbles. *Gyrinidæ* (whirligig beetles) were rather numerous. No algæ were visible. Water was slightly turbid, with slow current of about 0.2 foot per second.

Sediments.—Bottom mud was very soft and livery, without special odor, except that of clay, and was grayish in color. Organisms were relatively few in this mud, as compared to the large numbers usually found in the sediments of the Illinois River. Subsequent samples of mud (from the Spoon) confirm this statement, as will be seen.

On this occasion, 1 liter of mud yielded a very few (7) tubificid worms. May-fly larvæ and nymphs were moderately abundant, the sample yielding 12 of the large *Hexagenia*. Four *Tanytus* larvæ and a small bivalve or two completed the list of mud organisms.

In late August (the 27th) practically the same population was found in this very soft, dark, nearly odorless mud, the 1-liter sample yielding 5 tubificid worms, 12 *Hexagenia*, 4 larval chironomids (all *Tanytus*), and 5 small bivalves. The water was quite turbid. No water bloom was visible, but beetles belonging to the *Gyrinidæ* were abundant. (See Table 38.)

The summer plankton, 1921.—Summer catches averaged 1,150 units for the 12 weekly samples. Index organisms averaged 146 units, of which 27 units were pollutional and 127 units indicated cleaner water. The total plankton average showed 1,110 units of oxygen producers, or over 96 per cent. The minute green algæ were greatly predominant, constituting about 84 per cent of the entire plankton. The flagellates, next in point of abundance, constituted less than 9 per cent of the total. (Tables 6 and 40.)

Diatoms were scarce in the summer plankton, *Pleurosigma* appearing in 4 of the 12 samples, and *Synedra* and *Navicula* in 2 each. Blue-green algæ were found sparingly in 1 sample only. Green algæ were abundant, *Pleurococcus* and minute unknown cells appearing in every sample, and constituting the chief algæ constituent, *Dictyosphaerium*, *Scenedesmus*, *Tetraspora*, *Closterium* and *Pediastrum* were found in only three or four samples. Of the flagellates, *Trachelomonas* was found in 4 samples, *Cryptomonas* in 3, and *Chlamydomonas* and *Euglena viridis* in 2 each. Ciliates were of occasional occurrence only, the pollutional forms *Colpidium*, *Carchesium*, and *Vorticella* in a single sample each, and the cleaner form *Codonella* in two samples. Rotifers were absent. Crustacea naupleii were found in two samples. (See Table 40.)

TABLE No. 39.—Summary of plankton findings for each month
AVERAGES AT STATION SPOON RIVER

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms							
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indefinite and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Polliniferous	Cleaners		
1901												
June	1,003	33	1,036	526,000	1,012	26	6	40	0	71	1,013	636
July	800	189	1,015	143,300	606	144	41	27	66	120	636	636
August	1,106	114	1,300	300,000	1,179	106	9	10	12	164	1,137	1,137
September	1,170	44	1,220	384,000	1,166	26	18	13	30	13	1,160	1,160
October	1,428	87	1,510	270,500	1,403	63	34	20	0	114	1,396	1,396
November	966	51	1,000	105,500	944	37	34	14	8	78	930	930
December	477	26	515	65,400	477	26	15	0	0	85	463	463
1902												
January	375	30	414	36,800	375	21	18	0	19	20	367	367
February	717	74	791	143,800	714	23	33	3	6	40	747	747
March	803	121	923	380,500	803	17	104	0	17	17	800	800
April	480	44	523	87,800	467	30	15	2	2	81	479	479
May	680	134	824	74,500	690	108	26	0	0	219	605	605
June	686	189	775	91,000	667	102	36	0	29	140	613	613
July	3,301	243	3,544	735,200	3,301	230	13	0	3	1,412	3,130	3,130
August	1,039	193	1,331	65,400	1,030	166	26	0	76	213	963	963
Averages for 11 months	904	96	900	179,670	897	68	31	7	13	191	888	888

TABLE No. 40.—Classification of plankton organisms
STATION SPOON RIVER, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopoda	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	Total
1901											
June	18		964	40		36	3	1			
July			803	27		144			11	20	
August	102		1,076	10		106	2			7	
September	26		1,140	13		26	2			16	
October	54		1,349	20	4	63				30	
November	131		813	14	1	27	3			20	
December	19		446			26				15	
1902											
January	43		333			31	18				
February	57		667	5		23	6			48	
March	136		804			17	17			66	
April	99		368	2		29	4	1	6	5	
May	131	8	552		1	108	1	3	10	11	
June	9	8	619			102	15			31	
July	186	22	3,081			230	1			4	
August	63	33	983			166	13	1		12	
Averages:											
Summer	47		964	23		99	2		4	13	1,163
Autumn	81		1,048	15	2	37	2			19	1,304
Winter	29		479	1		26	8			21	574
Spring	116	3	564	1		51	7	1	6	35	806
Summer	60	23	1,436			161	10			13	1,720

September, October, and November, 1921.—In late September the water of the Spoon was still somewhat turbid, its usual condition. Turbidity had been unusually high in mid-September. Mud samples were dark in color, exceedingly soft, but without any of the odor which is associated with the active decomposition of organic matter. Plant detritus was abundant. A liter of the mud yielded, comparatively speaking, a very few (9) tubifex worms, moderate numbers (7) of a cleaner-water insect larvæ (*Heragenia*), and an occasional larva of *Chironomus* and of *Ceratopogon*.

Late October samples showed essentially the same conditions as above, the water turbid, the dark-colored, odorless mud very soft and smooth, plant detritus present, together with a few tubifex worms and insect larvæ, and an occasional small bivalve.

The autumn plankton.—Eleven weekly samples yielded an average of about 1,200 units of plankton, of which amount the index organisms averaged 80 units. The latter averaged 12 units of pollutational forms.

The make-up of the plankton was very similar to the summer yield. Minute green algæ constituted 87 per cent of the total. The lower temperatures of autumn seemed to affect both the flagellates and the diatoms, encouraging the latter, but inhibiting the former, so that the summer average of 47 units of diatoms and 99 of flagellates was changed, in the autumn catches, to 81 units of diatoms and 37 of flagellates.

Navicula and *Synedra* were the leading diatoms, these being found in about half the samples. *Pleurosigma* appeared in three samples and *Tabellaria flocculosa* in one only. The blue-green algæ were absent. The abundant green algæ consisted chiefly of *Pleurococcus* and unknown minute cells (in all samples), with *Scenedesmus*, *Tetraspora*, and one or two others occasional.

The rhizopods *Arcella* and *Diffugia* were each found in a single sample. The flagellates, decreasing in numbers, also showed diminished variety, only *Cryptomonas* (2 samples), *Euglena viridis* (2 samples), and *Trachelomonas* (1 sample), being found. Of the ciliates *Vorticella* was found in three samples, and *Carchesium* and *Colpidium* in one each. Rotifers and crustacea were absent.

December, 1921, January and February, 1922.—A visit to this region early in December found the water so rough on account of wind that the Illinois River could not be crossed in safety with a small boat. It was possible to reach the Spoon River, however, by crossing the Illinois River bridge and following the railroad track from East Havana up to the point where it crosses the Spoon River, about a mile above the usual sampling point.

Water was very high on account of recent rains and the low banks of the Spoon near its mouth were nearly covered with water. The stream itself was turbulent and very muddy, though I was told by

local rivermen that the water had been clear for several days before the rains of the preceding day.

Mud samples obtained here were very similar to those at the regular sampling point. The mud was dark, very soft, and without odor. A few tubifex worms (7), moderate numbers of the cleaner-water larva *Hexagenia* (5), and one or two larvae of *Chironomus* and of *Corethra* were obtained from one liter of mud.

At the time of our trip in January (1922) the Spoon River was frozen over and no samples could be obtained.

The winter plankton.—Twelve weekly samples averaged 573 units of organisms, with an index content of 48 units, of which 8 units were pollutional forms.

This low yield of winter plankton (less than half the autumn yield) again showed a high preponderance (83 per cent) of minute green algae, a few diatoms, a few flagellates, and practically nothing else.

Asterionella was the leading diatom, appearing in five samples. *Synedra*, *Navicula*, and *Tabellaria fenestrata* were found in two or three samples each. *Pleurococcus* and minute unidentified cells were again the leading green forms, appearing in every sample, with *Scenedesmus* and *Tetraspora* occasional. Of the flagellates, *Cryptomonas* was found in eight of the twelve samples. *Chlamydomonas* and *Euglena* were occasional. The pollutional ciliates *Vorticella* and *Colpidium* were found in five and three samples, respectively. *Codonella* was found once. Rotifers and crustacea were absent.

March, April, and May, 1922.—In early March the water was very turbid. Mud samples seemed of good quality, having only a very slight odor, and yielding a very few tubifex worms, and larvae of *Hexagenia* and of *Tænipteryx*.

In April the water was unusually high, with banks submerged and water completely covering an adjoining cornfield. Much drift was lodged among trees and bushes along the submerged banks. Current was hardly perceptible, and the direction of water movement was not down the Spoon Channel as usual, but across the channel and over the submerged banks and lowlands.

The yellowish soft "soupy" bottom mud had practically no odor. Only four tubificid worms were found in a 1-liter sample. No other organisms were found. Similarly, in May the bottom mud was characteristically yellowish and semiliquid, with no odor, and yielded the same number (four) of tubificid worms and two of *Chaetogaster* also. It seemed evident from the physical condition of this mud and from the very small population of worms, etc., that this was a practically new deposit from the tremendous amounts of silt that were carried by the water of the Spoon during these spring months. (Table 38)

The spring plankton.—Twelve samples yielded an average of 806 cubic standard units of total plankton, of which the chlorophyll-bearing forms comprised 756 units or 94 per cent. Index organisms numbered 102 units, of which 7 units were known pollutional forms and 95 were of the cleaner types.

Groups of organisms making up the plankton showed minute green algae to be far in the lead, comprising 73 per cent of the total (see Table 40).

Specific organisms were essentially as follows: *Synedra* and *Asterionella* were the leading diatoms. *Pleurococcus*, of the green algae, was found in all samples, with *Scenedesmus* and *Tetraspora* in four samples each. Of the flagellates, *Cryptomonas* appeared in 7 of the 12 samples. Other flagellates were only occasionally present. The cleaner water ciliate *Codonella* was found in five samples and the pollutional forms *Colpidium*, *Carchesium*, and *Vorticella* in two samples each. Rotifers were only occasional, *Polysartha*, *Asplanchna*, and *Anuraea cochlearis* being found in a single sample each. Crustacea were only occasional also.

June, July, and August, 1922.—The very high water prevalent in spring had now given place to normal levels, and turbidity was moderate in amount at the time of our June visit. The deep deposit of thin, brownish, odorless bottom mud contained very few organisms, only five tubifex worms being found in a 1-liter sample.

In late July and early August the stream was beautiful with heavy foliage and festoons of vines along the banks. The very slight current was not sufficient to interfere with a heavy growth of waterbloom. Bottom mud was as usual very abundant, yellowish, odorless, and very soft, with only three tubifex worms found in a 1-liter sample. Our final visit in late August found the water quite turbid, but water bloom was abundant. Bottom mud was a little darker in color, very soft, and with practically no odor. No tubificid worms were found, but the liter sample yielded 15 chironomid larvae, seven of which were *Tanytus monilis*. One small bivalve was found also.

The summer plankton, 1922.—Fourteen weekly collections showed an average total plankton of 1,720 cubic standard units, more than double the average spring yield of 806 units. Chlorophyll-bearing, oxygen-producing organisms showed even more than their usual predominance, there being almost 99 per cent of these in the total plankton yield. Index organisms averaged 621 units in this summer plankton, 33 units being pollutional and the remaining 588 units made up of those organisms characteristic of cleaner water. It will be noted that these cleaner organisms outnumbered those which are characteristic of polluted water 15 to 1 in these summer averages. (See Table 40.)

The universally high percentage of chlorophyll-bearing organisms referred to above was due largely to an extensive growth or "pulse" of *Actinastrum*, which constituted the leading organism in the plankton sample of July 27, forming, 3,614 units of the total green-alga contingent of 7,492 units. (See Table 54, Spoon River.) The total plankton in this sample amounted to 7,962 units. Thus, in this instance, a single kind of organism made up of 45 per cent of the total plankton.

Specific organisms appearing in this summer plankton were chiefly as follows: The diatoms *Synedra*, *Navicula*, and *Pleurosigma*, each appeared in 5 or 6 of the 14 samples; leading green alga were *Pleurococcus* in all samples, *Polyedrium*, *Tetraspora*, and *Scenedesmus* in 7 samples each, *Actinastrum* and *Calastrum* in 4, and occasional small amounts of *Raphidium*, *Closterium*, *Gonium*, *Eudorina*, and *Dictyosphaerium*. Flagellates were represented by *Cryptomonas*, *Trachelomonas*, and *Euglena* in 7 or 8 samples each, *Chlamydomonas* in 3, *Euglena viridis* in 5, and *E. oxyuris* in 3. The most frequently found ciliate was *Vorticella* (in 6 samples), with *Codonella* in 4, *Carchesium* in 3, and a single occurrence each of *Tintinnus*, *Paramacium*, and *Epistylis*. Rotifers were practically absent, as were also crustacea. (See Table 40.)

Discussion.—The outstanding characteristics of the Spoon plankton are: (1) the relatively large amount; (2) the high percentage of chlorophyll-bearing organisms; (3) the comparatively small numbers of pollutional forms.

The relative plankton yield of the Spoon is best shown by an inspection of Tables 28 and 29, where it will be seen that only three other stations show a heavier average yield in winter and only four in summer. On an 11 months' basis, as shown in Table 5 (column marked "Total"), the Spoon is excelled by only three stations.

It is interesting in this connection to consider the results of Doctor Kofoid's study^{*} of this same stream in 1896-1898, prior to the opening of the Chicago Drainage Canal. At that time (a) the current of the Spoon River was scarcely perceptible at low water, but the stream was subject to frequent flushings by local floods, at which times the current was so strong that a boat could enter it with difficulty. This frequent renewal of the water operated to keep plankton yield at a very low point, (b) apparently because of lack of sufficient time for breeding. This was aptly illustrated (c) by the fact that, in 1897, floods were very infrequent, the water of the Spoon River was at a low level, was stable, and the greatly increased time available for multiplication of plankton was at once shown by the heavy yield during that year, as compared to the very slight yield during 1896 and 1898, when the customary instability of levels prevailed.

^{*} Illinois State Lab. Nat. Hist. Bulletin, Vol. VI, Art. II, 1900; (a) pp. 341, (b) p. 308, 441, (c) pp. 348.

On an average, the Illinois River at Havana produced nearly five times ⁶ as much plankton as did the Spoon River, the average yield of the two streams being 2.19 parts per million (by volume) and 0.465 part per million, respectively.

In 1900 the addition of lake water and Chicago sewage incident to the opening of the sanitary canal raised the average level of water in the Illinois 3.4 feet ⁷ at Havana. The effective drop of the Spoon River in its lowest portion is thus reduced by this amount, the water of the lower reaches is impounded to some extent, and the current is very slow. The greatly increased time factor thus afforded plankton organisms in the Spoon River is in all probability responsible for the present heavy yield as compared with Kofoid's results. The 52 weekly plankton samples taken in the Spoon River near its mouth during June, 1921, to August, 1922, average 8.9 parts per million (by volume) of organisms, and simultaneous collections from the Illinois River at Havana just above the mouth of the Spoon River average 10.25 parts per million. It is thus apparent that the partial impounding of the Spoon River waters incident to the raising of the level of the Illinois has provided the adequate time period for plankton growth in the former stream which was wanting previous to the opening of the drainage canal.

The relatively very high proportion of chlorophyll-bearing plankton organisms seems to be in keeping with the similar findings at all stations, both in the main stream and in tributaries. (Table 40.)

The small proportion of pollutorial organisms in the Spoon River plankton is the logical result of the absence of any considerable amount of sewage from the few towns in its watershed, receiving only a moderate amount from Lewistown and Canton, both of these towns being comparatively small.

It will be noted, by reference to Tables 50 and 51, that (1) the winter yield of total plankton in the Spoon River is about 50 per cent of the summer yield; (2) that index organisms in winter are outnumbered more than 6 to 1 by those in summer, but (3) the percentage of pollutorial forms in these index organisms is 22 in winter as compared to 6 in summer.

The assortment of bottom organisms is such as to give further testimony to the effect that the Spoon River is not heavily polluted. The only definitely pollutorial form present is tubificid worms and these average only 7 ⁸ per liter of mud. *Chironomus* larvae were of occasional occurrence only, but of 28 specimens taken during the 14 months, 17 were identified. These were *C. digitatus* (2), *C. decorus* (8), and *Tanytus monilis* (7), all these being normal to an environ-

⁶ Pages 105, 278, in Ill. St. Lab. Nat. Hist. Bull.; Vol. VI, Art. II.

⁷ Biology of the Upper Illinois River. Forbes and Richardson, 1915, p. 486.

⁸ This worm (*Limnodrilus*) is often found in small numbers (under 50 per liter of mud) in places where the water is known to be relatively pure. Birge and Jolley (1) record their presence in Lake Michigan.

ment⁹ that is not excessively polluted. The large May-fly larva *Hexagenia* was common, averaging three per liter. This is apparently a clean-water organism according to investigations by Dr. S. A. Forbes,¹⁰ who found that nearly a fifth of the entire amount of food consumed by various adult fishes consisted largely of *Hexagenia* larvae. The fishes examined by Doctor Forbes were taken from various waters in Illinois, including rivers, ponds, Lake Michigan, Mississippi and Ohio Rivers, etc. This work was done in 1876 to 1887, which was previous to the heavy pollution of either the Illinois or the Ohio Rivers. Also, Doctor Needham found¹¹ *Hexagenia* to be common in Little Clear Creek, a small unpolluted trout stream in the Adirondacks.

STATIONS 100 AND SANGAMON RIVER

As indicated in Table 2, page 30, these two stations are located in the lower river. Being only 22 miles below the Havana sampling point, this main river station (station 100) presumably represents the further progress of the purification process which seems evident at the Havana station, as there is no further pollution of consequence added to the river between Havana and station 100.

Inspection of the bottom sediment, Tables 35 and 43 (from stations 122 and 100, respectively), reveals marked similarity as to physical conditions and somewhat less similarity as to predominating organisms in these sediments. The larger variety is to be found at station 122, but the sludge worms here outnumber those at station 100 about 3 to 1. Another seemingly significant item is the absence of living snails at station 122, while these are occasionally present (as shown by six months' samples) at the lower station.

TABLE NO. 41.—Summary of plankton findings for each month

AVERAGES AT STATION 100

Date	Plankton catch, cubic standard units in 1 c. of water											
	Total catch				Total organisms							
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollivorous	Cleaners		
1901												
June.....	305	511	816	75,000	305	190	331	0	177	585		180
July.....	551	433	984	85,000	550	197	336	31	341	511		300
August.....	421	306	727	100,000	421	17	330	1	230	380		361
September.....	641	303	944	37,000	644	45	300	17	144	307		600
October.....	803	300	1,103	65,000	803	74	194	0	74	307		600
November.....	847	55	902	11,000	847	44	13	0	52	190		710
Average for 6 months.....	728	307	1,035	66,000	728	100	193	5	197	345		400

⁹ Bull. Ill. Nat. Hist. Survey Vol. XIV, Art. IV, pp. 43, 51, 56.¹⁰ Bull. Ill. State Lab. Nat. History, Vol. II, Art. VIII, pp. 477, 484.¹¹ Aquatic Insects in the Adirondacks, Bull. 47 of N. Y. State Museum, pp. 490, 498.

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TABLE No. 42.—*Classification of plankton organisms*

STATION 100, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c.c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	
1921											
June 1	20	220	135	-----	135	190	92	3	64	27	-----
July	8	423	499	21	5	197	74	7	126	26	-----
August	8	216	196	-----	9	77	106	10	51	4	-----
September	100	165	719	17	2	43	172	8	13	5	-----
October	160	135	569	-----	19	91	66	7	10	9	-----
November 1	572	55	214	5	5	44	4	3	1	-----	-----
Averages:											
Summer	10	312	323	9	30	152	118	7	87	18	1,006
Autumn	218	107	558	8	9	62	96	6	9	6	1,079

1 2 samples only.

Similar inspection of the plankton tables 37 and 41 from these two stations and for the six months' period indicated shows: (1) A total plankton content greater by 26 per cent at station 122 than at station 100; (2) an index organism content greater also, but by only 19 per cent; and (3) a pollutional organism content (of the index organisms) which differs but little, being 39 per cent at station 122 and 36 per cent at station 100.

TABLE No. 43.—*Bottom sediments*

STATION 100

Date	Bottom sediments: (1) Physical conditions, and (2) Predominating organisms
1921	
June 13	(1) Dark, granular; no odor. Much fine detritus. (2) Tubificid worms 24. Chironomus larvae, C. digitatus 11. A few (14) young mussels and moderate amounts of the bryozoans Paludicella and Plumatella.
July 30	(1) Dark, grayish, granular, slight odor or none, and much plant detritus. (2) Tubificid worms 12. C. digitatus larvae 2. Small amount of the bryozoan Paludicella and occasional colonies of Pectinatella as large as the two fists.
Aug. 29	(1) Dark, granular, no odor. Fine detritus of plants abundant. (2) Tubificid worms 18, a few snails, and an occasional larva of Chironomus and of May fly. The bryozoan Paludicella present in small amounts.
Sept. 22	(1) Dark and granular, with much fine detritus of plants. (2) Tubificid worms 1. An occasional snail, and larva of Chironomus and of caddis fly. Small amounts of Urnatella and Paludicella present. The Chironomus larvae were C. digitatus and C. lobiferus.
Oct. 15	(1) Dark, granular, odorless or nearly so. Large amount of fine plant detritus. (2) Tubificid worms 4. An occasional larva of Chironomus (not identified) and of May fly (Hiragenia), and a very few young bivalves.

The classification tables 36 and 42 show only negligible variations as to the kinds of organisms present and their relative abundance. During the six months' period as a whole, diatoms constituted 14 per cent of the plankton at station 100 as compared to 8 per cent at station 122, but all the other quantitatively important groups differed but little when placed on a per cent basis. Thus the blue-green algae differed by 1 per cent, the green algae by 5 per cent, the flagellates by 1 per cent, and the ciliates by 3 per cent.

TABLE NO. 44.—Summary of plankton findings for each month
AVERAGES AT STATION SANGAMON RIVER (MOUTH)

Date	Plankton catch, cubic standard units in 1 c. c. of water										
	Total catch				Total organisms						
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutional	Cleaner	
1921											
June.....	1,438	877	2,305	70,000	1,438	646	226	0	310	995	1,601
July.....	1,805	266	2,071	85,800	1,805	310	36	0	694	326	851
August.....	1,968	306	2,274	136,100	1,968	165	41	5	474	439	1,272
September.....	1,223	306	1,529	76,400	1,305	333	74	19	190	480	860
October.....	1,387	304	1,691	74,500	1,387	243	41	0	131	511	1,051
November.....	994	111	1,105	35,200	994	90	13	0	50	488	567
Averages for 6 months.....	1,466	345	1,811	80,170	1,464	266	78	4	306	572	934

Sangamon River samples for this six months' period show in Table 44 a total plankton content exceeding, month by month, even the heavy yield from the Illinois River at station 122. (See Table 37.) The per cent of pollutional forms in the index organisms is about the same as at station 100, being 36 per cent for the latter place and 35 per cent for the Sangamon River samples. Inasmuch as the latter stream joins the Illinois River about 1 mile below station 100, it would seem that the Sangamon adds no appreciable pollution¹² to the main stream, so far as is indicated by these plankton organisms.

TABLE NO. 45.—Classification of plankton organisms
STATION SANGAMON RIVER, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water									
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.
1921										
June.....	152	80	1,227			649	200	3	17	
July.....	16	677	1,113			229	10	6	16	4
August.....	44	456	1,462	5	2	165	6	4	14	16
September.....	16	110	1,070	19		352	62	2	6	5
October.....	254	119	1,015			243	35	4		22
November.....	275	112	607			199	1	12		
Averages:										
Summer.....	1	483	1,200	2	1	262	45	5	15	7
Autumn.....	1	113	970	6		212	41	4	3	10

* 2 collections only.

¹² See pages 162 and 164 relative to Sangamon River and Spoon River.

STATION 25. BELOW KAMPSVILLE

General conditions.—The 95-mile stretch of river between Havana and the final sampling station within 25 miles of the mouth of the Illinois is a fairly direct course, with slight curves only, an occasional island, banks wooded, for the most part with a fringe of trees adjoining the farm lands which occupy most of the flood plains on one side or the other or bordered with miles of levee by which thousands of acres have been reclaimed for agricultural purposes from the low swamps or shallow backwaters that formerly occupied much of the land adjacent to the stream.

There are no towns of large size on this lower portion of the river. Beardstown is the only place of considerable size. The total population is about 73,000, of which about 62,000 are served by sewers, the sewage being discharged, untreated, into the river.

Aside from the organic matter incident to the drainage of fertile prairie and cultivated farm lands, together with the small amount of waste from the town mentioned, there is no other source of pollution, with the possible exception of the Sangamon River which enters from the east at a point about 100 miles upstream from the mouth of the Illinois.

This stream, somewhat larger than the Spoon, has the city of Springfield, Ill., located upon it about 60 miles upstream, and the sewage and waste of this town of 60,000 people are discharged, untreated, into its waters, but only about half of the population stated is served by sewers. During passage of the slow, meandering stream, these wastes have to a great extent been disposed of, but the water at the stream's mouth yet shows a plankton content that indicates presence of pollution, the percentage of pollutionsal forms in the index organisms in summer being 38, as compared with 18 per cent of pollutionsal forms in the unpolluted Spoon River during the same months.¹³

A dam at La Grange and another at Kampsville operate to produce temporary impounding of the water when levels are low, the fall over the dam's crest being about 3 feet in each case. During high levels these low cascades are obliterated under several feet of water and there is no perceptible slackening of the current.

The river has every appearance of a clean stream in this lower portion. There is no unsightly floatage, and no odor. Except for frequent turbidity from silt, the water is fairly clear; that is, there is no grayish flocculent suspended matter such as characterizes the water at Joliet and as far south as La Salle. So far as the unaided senses can determine, the lower Illinois is an ideal stream for boating and bathing, and its banks offer beautiful sites for residences.

¹³ June, July, August, September, and October of 1921.

There is, however, in all this lower river a peculiar condition which, for want of a better name, might be termed spotted turbidity. This is an actual condition of turbidity in spots, as if the water were being "roiled up" by some activity in the bottom mud, making the surrounding water distinctly turbid over an area varying in the different spots from 1 to perhaps 10 or 12 square yards. The water bordering these spots meantime is relatively clear for the time being. The phenomenon may best be observed from the upper deck of a moving steamer, from which point of vantage a large number of these spots will be observed apparently occurring in about equal abundance in all portions of a given section of the stream. The writer made careful and continuous observations of these turbidity spots at various times during river trips and particularly on one occasion during a trip by packet from Kampsville to Peoria, August 27, 1922, at which time the following entry was made in the field notes:

Turbidity in spots very much in evidence at many places and less noticeable in some sections. However, this condition prevailed from Kampsville up to below Naples, 35 or 40 miles above Kampsville. At about this place uniform turbidity prevailed apparently of about the same degree as the lesser turbidity in the spotted portions at Kampsville. Some 4 miles above Naples and below the bridge at Meredosia the spots were again seen, but were less marked. Just above the bridge, or rather above and below this bridge, they could not be made out, but less than a mile above the bridge they were apparent but not distinct. This condition varied with "total invisibility" up to La Grange Dam. In La Grange Dam the spotted turbidity again was visible, being very plain in places but seen with difficulty in rather the greater majority of cases. This latter condition prevailed up to Beardstown, when the coming of darkness made further observation impossible.

At 6 o'clock the next morning the river just below Peoria showed practically clear water and no spots of turbidity were visible. This was below the lowermost railroad bridge.

On August 23 also this spotted turbidity was noted from the highway bridge at Havana. Apparently the turbidity spots were being produced in every portion of this section of river. They were not confined to the channel nor to the portions near the margins, but were about equally abundant in every part of the stream, which is about 800 feet wide at this point.

Local fishermen claim that this roiling of the water is caused by carp and catfish "nosing" about in the bottom mud. Other than this the writer has never heard any explanation of the phenomenon.

It is obvious that this spotted turbidity can be observed only when the water as a whole is relatively low in turbidity. It is also true that in a long series of observations the average or mean turbidity of this portion of the river will be considerably increased by these many spots of relatively high turbidity. As an illustration of this, it is noted that the average turbidity of water samples taken

during July, August, and September at stations 179, 122 (Havana), and 25 (Kampsville) is only 32 at the uppermost station (179, which is at the head of Peoria Lake) as compared with 152 at Havana and 397 at Kampsville. Also the writer has never observed this spotted turbidity in Peoria Lake, though visited many times.

This stretch of river is practically free from any considerable growth of aquatic plants, either emergent or submerged, including algae. Even the large shallow-water area (a square mile or two) just below the mouth of the Sangamon and known locally as Muscooten Bay seemed almost devoid of the heavy growth of submerged aquatics and algae usually found in such an environment. It seems probable that the frequent high water makes it difficult for such plants to maintain any considerable growth. This would seem to apply particularly to the main stream, but it seems inadequate explanation for the lack of submerged and emergent vegetation in such an environment as Muscooten Bay.

TABLE NO. 46.—Bottom sediments

STATION 25, KAMPSVILLE

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms
1921	
June 15.....	(1) Dark, granular, no odor. Much detritus. (2) Tubificid worms average 6 per liter of mud. Bivalves 36, Chironomus larvae: <i>C. digitatus</i> 4, <i>Procladius concinnus</i> 1. May-fly nymphs as follows: <i>Heptagenia</i> 2, <i>Hexagenia</i> 1. Caddis larvae (<i>Hydropsyche</i>) 7. Small amount of bryozoa and occasional <i>Chaetogaster</i> , and an unknown beetle larva. Caddis-larva cases were numerous.
June 15 (in the dam at Kampsville).	(1) Dark, granular, no odor. Much plant detritus. (2) No tubificid worms. Occasional bivalve, snail, and unknown beetle larva. Leeches (<i>Glossiphonia</i>) average 3 per liter of mud, and <i>Tanytus</i> larvae 2. May-fly nymphs as follows: <i>Heptagenia</i> 1, <i>Caesio dimorpha</i> 6, <i>Hexagenia</i> 4. Caddis larvae (<i>Hydropsyche</i>) 239. Chironomus larvae: <i>C. flavus</i> 29, <i>Procladius</i> 4, <i>Planarians</i> 4. The bryozoa <i>Plumatella</i> and <i>Paludicella</i> abundant.
Aug. 2.....	(1) Dark, granular, without odor. Plant detritus abundant. (2) Tubificid worms 14, Chironomus (<i>C. digitatus</i>) 1, young mussels 9, and an occasional leech and larva of May fly and of caddis fly.
Aug. 30.....	(1) Dark, granular, and without odor. Detritus of plants abundant. (2) Tubificid worms 10. An occasional bivalve, snail, and larva of May fly and of caddis fly. The bryozoa <i>Paludicella</i> moderately abundant, and small amounts of <i>Fredericella</i> and <i>Urnatella</i> .
Sept. 17.....	(1) Dark, granular, odorless. Much detritus present. (2) Tubificid worms 7, small bivalves 3, May fly 2, <i>Hydropsyche</i> 1, an occasional leech, and Chironomus larva, and small amounts of bryozoa.
Oct. 17.....	(1) Some sand with the mud, no odor. Very large amount plant detritus. (2) Tubificid worms average 30 per liter of mud. Bivalves 4, one of which was <i>Unio</i> . Chironomus larvae (<i>C. digitatus</i>) 1, unidentified 1. May-fly nymphs (<i>Caesia</i>) 2. Caddis (<i>Hydropsyche</i>) 4.
Nov. 23.....	(1) Some sand present. Much detritus of plants also. (2) Tubificid worms 29, young bivalves 4, Chironomus larvae, <i>C. digitatus</i> 2, <i>Tanytus</i> 1. Occasional caddis-fly larva (<i>Hydropsyche</i>) and nymph of dragon-fly. May-fly nymphs (<i>Hexagenia variabilis</i>) 7. Bryozoa as follows: <i>Plumatella</i> abundant, <i>Paludicella</i> and <i>Urnatella</i> present in small amounts.
1922	
Jan. 12.....	(1) Dark, with a little sand. Moderate amount plant detritus present. (2) Tubificid worms 36, young mussels 7, unknown beetle larva 7, May-fly nymphs (<i>Hexagenia</i>) 10, caddis larvae (<i>Hydropsyche</i>) 2, Chironomus larvae, <i>C. digitatus</i> 7, <i>C. viridis</i> 3, <i>Tanytus</i> 2, unknown 2.
Feb. 18.....	(1) Dark, grayish, a little clay intermixed. Plant detritus present. (2) Tubificid worms 5, small mussels 2. Chironomus larvae as follows: <i>C. digitatus</i> , 5 <i>Procladius concinnus</i> 2, <i>Tanytus monilis</i> 3, unknown 3, ceratopogon larvae 2.
Mar. 16.....	(1) Dark, without odor. Plant detritus in moderate amount. (2) Tubificid worms 16, young mussels 2, caddis larvae (<i>Hydropsyche</i>) 5, larvae of black fly (<i>Simulium</i>) 13. An occasional May-fly larva (<i>Heptagenia</i>) and Chironomus. The bryozoa <i>Plumatella</i> and <i>Paludicella</i> in moderate amounts.

NOTES.—Unless otherwise stated, bottom samples are collected at or near the regular sampling station at point 25, a few miles below Kampsville.
On account of usually high water, field work was practically suspended at Kampsville during April, and bottom samples were not obtained.

TABLE No. 46.—Bottom sediments—Continued

STATION 25, KAMPSVILLE—Continued

Date	Bottom sediments: (1) Physical conditions, and (2) predominating organisms
1922	
May 17.....	(1) Dark, rather tough, without odor. Moderate amount of plant detritus present. (2) Tubificid worms 3, young mussels 19, caddis larvæ (<i>Hydropsyche</i>) 2. Chironomid larvæ: <i>C. digitatus</i> 1, <i>Procladius concinnus</i> 1, unidentified 1. An occasional larva of <i>Ceratopogon</i> , simuliid, and dragon-fly. Small amounts of <i>Paludicella</i> present.
June 14.....	(1) Much sand on east side. Mud at center and west. Much plant detritus present. (2) Tubificid worms 4, young bivalves 57, Chironomid larvæ, <i>C. digitatus</i> 2, unidentified 3, caddis larvæ (<i>Hydropsyche</i>) 3. An occasional larva of <i>Ceratopogon</i> , May fly (<i>Hexagenia</i> and <i>Caenis diminuta</i>) and Odonata. <i>Paludicella</i> present.
July 14.....	(1) Color dark, no odor. Much plant detritus present. (2) Tubificid worms 5. Small bivalves rather numerous (181) and partly grown ones in moderate number (53). Snails 11, May-fly nymphs (<i>Hexagenia</i>) 12, a few chironomid larvæ, and an occasional <i>Ceratopogon</i> larva. The bryozoan <i>Paludicella</i> present.
Aug. 26.....	(1) Grayish, somewhat tough, without odor. Moderate amount detritus present. (2) Tubificid worms 37. Young bivalves 206, partly grown ones 218 in 1 liter of mud. May fly-larvæ: <i>Hexagenia variabilis</i> 4, <i>Caenis diminuta</i> 1. An occasional larva of Chironomid, unknown beetle, dragon fly, and Corethra. The bryozoan <i>Paludicella</i> present in small amount.

Bottom sediments, June, July, and August, 1921.—Samples were obtained by use of the mud scoop at the three established points across the channel. Twelve samples thus taken during June to August, inclusive, may be adequately and briefly described as follows:

Color, dark or grayish; granular or friable rather than sticky. Not spongy. No special odor, aside from a clean "earthy" odor. Usually much detritus, chiefly fragments of leaves or bits of bark, chaff, etc., formed a part of the catch.

Average content of organisms in one liter of mud was as follows: Tubificid worms 8, mussels 12, Chironomid larvæ 11, caddis larvæ 62, May-fly larvæ 4, leech 1, *Ceratopogon* larvæ 1, Planarians 1, larvæ of an unknown beetle 1, and an occasional snail. Bryozoa were moderately abundant.

The chironomid larvæ identified (80 of the total of 130) were as follows: *C. flavus* 55, *C. digitatus* 15, *Procladius culiciformis* 7, and *Procladius concinnus* 3.

All the caddis larvæ (a total of 740 in the 12 samples) were *Hydropsyche*.

Of the total of 42 May-fly larvæ, 40 were identified. *Caenis diminuta* was present to the number of 17. *Hexagenia* numbered 15, and *Heptagenia* 8.

The mussels were practically all of the sphaerid group, with only an occasional one of different variety. (Table 46.)

The summer plankton.—Twelve weekly collections taken during June to August, inclusive, averaged about 1,210 cubic standard units of total plankton per cubic centimeter of water. The index organisms averaged 737 units, and of these 37 per cent were pollutional forms. As to oxygen production the total plankton showed 69 per cent of chlorophyll-bearing, oxygen-producing forms. (Table 47.)

TABLE NO. 47.—Summary of plankton findings for each month
AVERAGES AT STATION 25

Date	Plankton catch, cubic standard units in 1 c. c. of water											
	Total catch				Total organisms							
	Organisms			Amorphous matter, etc.	Oxygen producers		Oxygen consumers		Index organisms		Indifferent and of unknown status	
	Plants	Animals	Total		Plants	Flagellates	Animals	Fungi	Pollutational	Cleaner		
1921												
June.....	93	505	598	175,000	86	80	426	7	27	462	109	
July.....	1,142	684	1,826	35,900	1,133	204	430	9	672	605	488	
August.....	818	258	1,076	87,100	818	101	157	0	121	264	691	
September.....	682	320	1,002	254,300	685	87	233	17	112	272	617	
October.....	1,043	317	1,360	60,100	1,043	185	132	0	196	437	737	
November.....	867	61	928	68,300	867	19	42	0	89	70	770	
December.....	606	36	642	62,100	606	20	16	1	8	91	542	
1922												
January.....	535	20	555	207,400	535	5	15	13	0	30	526	
February.....	705	47	752	70,000	690	0	47	6	2	44	706	
March.....	1,226	41	1,267	265,000	1,280	20	21	0	0	46	1,231	
April.....	810	13	823	51,000	780	0	13	20	0	132	690	
May.....	1,605	440	2,045	31,900	1,605	80	351	0	11	378	1,686	
June.....	1,203	191	1,394	94,600	1,203	70	120	0	53	225	1,008	
July.....	1,055	156	1,211	100,600	1,023	84	72	23	40	493	679	
August.....	693	117	810	26,000	693	55	62	2	26	291	405	
Averages for 11 months.....	901	178	1,078	93,170	904	58	118	7	71	226	780	

This chlorophyll-bearing group itself was made up as follows: Diatoms 5 per cent, blue-green algae 28 per cent, green algae 52 per cent, and flagellates 15 per cent. (Table 48.)

Synedra was the dominant diatom, appearing, however, in only 4 of the 12 samples. Blue-green algae were practically absent except for one very minute form which was quantitatively important despite its small size. This was a minute, lighter-than-water form greatly resembling *Beggiatoa* in general appearance in the killed material. The total catch of blue-green algae of all kinds in these summer samples aggregated 2,918 cubic standard units, and of this amount the minute blue-green referred to made up 2,682 units, or 92 per cent. I have thus far been unable to identify this alga. It seems probable that some of this unusual supply at station 25 originated¹⁴ in the small Pekin Lake, more than 100 miles upstream, where this alga was exceedingly abundant, and some, in all probability, came from the Sangamon River, 75 miles upstream from this station, where it was moderately abundant also. Judging from its abundance in these two places it seems reasonable to regard it as an organism characteristic of a more highly polluted habitat than usually obtains at station 25, but further observation is necessary before the sanitary status of this alga can be definitely stated.

¹⁴ See p. 148.

Green algae in these summer samples made up a large part of the total plankton, averaging 457 units or about 38 per cent. *Pleurococcus* and minute, unknown green cells were most abundant, with *Scenedesmus*, *Tetraspora*, *Dictyosphaerium*, and one or two others occurring less frequently. (See Table 48.)

TABLE NO. 48.—Classification of plankton organisms
STATION 36, MONTHLY AND SEASONAL AVERAGES

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates ¹	Rotifers	Crustacea	Spores, etc.	
1921											
June.....		60	17	7	3	80	350		24	40	
July.....	66	572	494	9	28	304	289	6	45	31	
August.....	43	55	600			101	112	2	10	60	
September.....	31	94	340	17		87	168	2	4	4	
October.....	93	140	305			133	107	16	8	4	
November.....	273	89	501		3	19	13	3		28	
December.....	71	28	311			30	1	2		13	
1922											
January.....	35		406	13	2	5	1	1		13	
February.....	74		626	6			2			45	
March.....	74		1,163			30		6		18	
April.....	90		600	30	9			4			
May.....	928	89	676		1	89	136	23	198	4	
June.....	181	24	998			70	54	4	8	55	
July.....	13	88	922	33		82	36	2		34	
August.....	42	28	628	2	6	55	36	8	2	6	
Averages:											
Summer.....	46	243	457	8	14	130	267	3	36	23	1,213
Autumn.....	128	113	626	5	1	104	97	8	8	27	1,115
Winter.....	60	6	551	7		7	1			36	660
Spring.....	796	28	865	4	1	43	47	12	76	9	1,506
Summer.....	85	42	845	10	2	69	43	8	4	31	1,134

¹ In all collections taken at Station 36 pollutional ciliates totaled 285 units (5 per cent) and cleaner-water ciliates totaled 5,149 units (95 per cent).

The rhizopod *Diffugia* was found in 6 of the 12 samples, and *Arcella* in one. The flagellates showed some variety, *Chlamydomonas*, *Trachelomonas*, and *Euglena viridis* appearing in seven samples each, and *Phacus*, *Cryptomonas*, and *Euglena oxyuris* less often.

The list of ciliates is not long. *Codonella* and *Tintinnus* each appeared in three-fourths of the samples and were by far the dominant ciliates. *Vorticella* was found in three samples, and *Colpidium* in a single sample.

Attention is directed to the fact that though the ciliate contingent of the plankton is quite large, averaging 267 units (about 22 per cent) of the average total catch of 1,210 units, a heavy preponderance of these ciliates (about 95 per cent) consists of the cleaner-water forms *Tintinnus* and *Codonella*,¹¹ the combined values of the pollutional forms *Vorticella* and *Colpidium*, also present, constituting only 5 per cent of the ciliate content.

¹¹ See discussion of these organisms, p. 137

Rotifers showed considerable variety, but no one kind was abundant and the total rotifer content was small, averaging only 3 units (less than 1 per cent) in the average total plankton during these summer months. The list of rotifers making up this small portion of the total plankton comprises *Anurxa cochlearis*, *Diglena*, *Brachionus* sp., *B. pala*, *Triarthra*, and *Rotifer tardus*.

Crustacea are few in number, but their relatively large size compensates somewhat, for the average content in these 12 summer (1921) samples is 25 units. During July crustacea were present in every sample.

Bottom sediments, September to November, 1921, inclusive.—The 12 bottom samples were dark in color, granular, practically odorless, and contained large amounts of fine detritus from plants. This latter material was no doubt due in part to the common use of corn-stalks and similar material in all this lower river region for the purpose of protecting the levees somewhat from the wash of the waves during times of high water, when breakage of the levee with consequent flooding of adjoining farm lands seems imminent.

During these autumn months the average content of 1 liter of mud was as follows: Tubificid worms 21, young muscels 4, Chironomus larvæ 4, May-fly larvæ 4, caddis larvæ 2, an occasional leech, and dragon-fly larvæ. The bryozoan *Plumatella* was moderately abundant, with smaller amounts of *Paludicella* and *Urnatella*.

Most of the 12 chironomus larvæ taken in the 12 collections were identified and found to be *C. digitatus* 7, *Procladius concinnus* 1, *Tanytus* sp. 2. Of the total of 31 May-fly larvæ, there were 20 of *Hexagenia variabilis*, 3 of *Hexagenia* species, 2 of *exilis*, and 6 unidentified. All the caddis larvæ (15) were *Hydropsyche*.

The autumn plankton.—During September to November, inclusive, 13 weekly samples averaged 1,117 cubic standard units of total plankton. The index organisms averaged 412 units, of which 139 were pollutional and 273 were cleaner-water organisms. The oxygen-producing contingent of the total plankton amounted to 87 per cent.

As in summer, the minute green algæ were the largest single group, forming about 57 per cent of the average total plankton. The diatoms also had increased relative value, advancing from 3 per cent in summer collections to 11 per cent in these autumn samples. Meantime the relative standing of the blue-green algæ had dropped from 20 per cent (in summer) to 10 per cent in the autumn catches, and the ciliates had decreased in similar fashion.

Specific organisms of the plankton were *Synedra*, the most abundant diatom; the minute unidentified filamentous blue-green alga (present in 10 of the 13 samples); *Pleurococcus*, minute cells, *Scenedesmus*, *Tetraspora*, and *Botryococcus* of the green algæ; *Cryptomonas*, *Chlamydomonas*, and *Euglena viridis* of the flagellates, and *Tintin-*

nus, *Codonella*, and *Vorticella* of the ciliates. A few rotifers representing at least four genera, and an occasional crustacean (in nauplius stage) completed the list. Many organisms occurred only occasionally, and in small numbers, the total number of genera represented in these autumn samples being in excess of 40.

Over 98 per cent of the ciliate contingent in these autumn collections was made up by the cleaner-water forms *Codonella* and *Tintinnus*. Pollutational ciliates were frequently present, but in very small quantity.

Bottom sediments, December, 1921, January and February, 1922.—No bottom sample was obtained in December. January and February samples, five in number, showed sediments that were apparently of good sanitary status, dark in color, clay in some, making them tough, rather than granular, no odor, except an "earthy" one, and moderate amounts of plant detritus in all samples.

Organisms in these five 1-liter samples averaged as follows per liter of mud: Tubificid worms 14, small mussels 6, *Chironomus* larvæ 15, May-fly larvæ 3, caddis larvæ 1, larvæ of unknown beetle 4. A very small amount of the bryozoan *Urnatella* was not uncommon.

Of the total of 75 *Chironomus* larvæ in these collections, 34 were *C. lobiferus*, 7 were *Procladius concinnus*, 8 were *Tanytus monilis*, 6 *C. viridis*, 1 *Protenches culiciformis*, 4 *Tanytus* sp., and 15 were not successfully identified. Of the 17 May-fly larvæ, all were *Hexagenia*, and caddis larvæ were all *Hydropsyche*. (Table 46.)

The winter plankton.—Twelve weekly collections showed an average total plankton of 660 cubic standard units. The index contingent averaged 54 units, of which 3 units were pollutational organisms and 51 units were cleaner-water forms. The total plankton showed 94 per cent of its organisms to be in the chlorophyll-bearing, oxygen-producing class.

Diatoms were present in every sample, and constituted, on an average, 9 per cent of the plankton. Blue-green algæ were only occasional, and made up less than 1 per cent. Green algæ were relatively abundant in every sample and averaged 84 per cent of the total plankton. (Tables 54 and 48.)

Synedra and *Asterionella* were the most abundant diatoms, *Pleurococcus*, *Scenedesmus*, *Tetraspora*, and minute green cells, unidentified, were the leading green algæ. Other organisms appeared in small numbers in a few of the samples, the ciliates *Codonella* and *Colpidium* being in two samples each, and *Tintinnus*, *Carchesium*, and *Vorticella* in one sample each. Rotifers and crustacea were practically absent.

Bottom sediments, March, April, and May, 1922.—On account of the very high water during April the field work was reduced to a minimum. In consequence of this no bottom sediments were obtained. The following data are based on 6 samples only, three being obtained in March and three in May.

Sediments were dark, somewhat stiff on account of presence of clay, had no special odor, and contained moderate amounts of fine plant detritus.

The average content of organisms per liter of mud was as follows: Tubificid worms 10, small mussels 11, larvae of *Chironomus* 2, of May fly 1, of caddis fly 4, of *Simulium* 7. Larvae of dragon fly, of stone fly, and of *Ceratopogon* were occasional. The bryozoans *Plumatella* and *Paludicella* were present in moderate amount.

The total of 11 *Chironomus* larvae consisted of *C. digitatus* 5, *Procladius concinnus* 2, unidentified 4. All the May-fly larvae were *Heptagenia*, and all the caddis were *Hydropsyche*.

The spring plankton.—Only one sample was obtained in April, on account of interruption of work occasioned by the prevalence of very high water. Four samples were obtained in March and three in May. The eight spring samples thus obtained averaged 1,508 cubic standard units of total plankton. The index organism contingent amounted to 184 units, of which only four units were known pollutional forms. The oxygen-producing (chlorophyll-bearing) portion of the total plankton amounted to 90 per cent.

The largest groups in these spring collections were diatoms, averaging 26 per cent, and green algae 59 per cent, respectively, of the total plankton. Crustacea averaged rather high (5 per cent), but this was largely due to the presence of one or two organisms of unusual size. (See Table 54.)

Synedra and *Asterionella* were the most abundant diatoms. Green algae were made up chiefly by *Pseudococcus*, *Scenedesmus*, *Tetraspora*, unknown green cells, and one or two other forms present in small quantity. Flagellates were only occasionally present, and in small quantity. Ciliates, too, were similarly few, *Tintinnus* appearing in three samples, and *Codonella*, *Epistylis*, and *Paramacium* in one each. Rotifers showed considerable variety, but the total quantity was small. The list includes *Brachionus*, *Anurxa*, *Pterodina*, *Polyarthra*, *Asplanchna*, and *Mastigocerca*. Crustacea were represented by *Cyclops* and *Bosmina*, in a single sample each.

The ciliate content, as noted above, was light, only 3 per cent of the total plankton, but even this light content was made up chiefly (over 95 per cent) of the cleaner-water ciliate *Tintinnus*.

Bottom sediments, June, July, and August, 1922.—Nine samples showed the usual good physical qualities, dark to gray color, no odor except that of clean earth, and moderate to large amounts of fine plant detritus.

The average organism content of these 1-liter bottom samples was as follows: Tubificid worms 9, small mussels 268, *Chironomus* larvae 4, May-fly nymphs 5, caddis larvae 2, snails 4, unknown beetle larvae 1.

Of the thirty-odd *Chironomus* larvae taken in the nine collections only a score were available for identification, and about half of these were successfully identified. Of *C. digitatus* there were nine and of *Procladius concinnus* there were two.

A total of 48 May-fly nymphs were obtained from these samples. Of these, 25 were *Hexagenia variabilis*, 16 were *Hexagenia* sp., 5 were *Caenis diminuta*, and 2 were not identified. The caddis larvae, 17 in all, were *Hydropsyche*.

The summer plankton, 1922.—Fourteen weekly collections during the three summer months yielded an average of 1,133 cubic standard units of total plankton. The oxygen-producing portion of this total plankton amounted to about 92 per cent. The index organisms averaged 403 units, of which 39 units (about 10 per cent) were pollutional

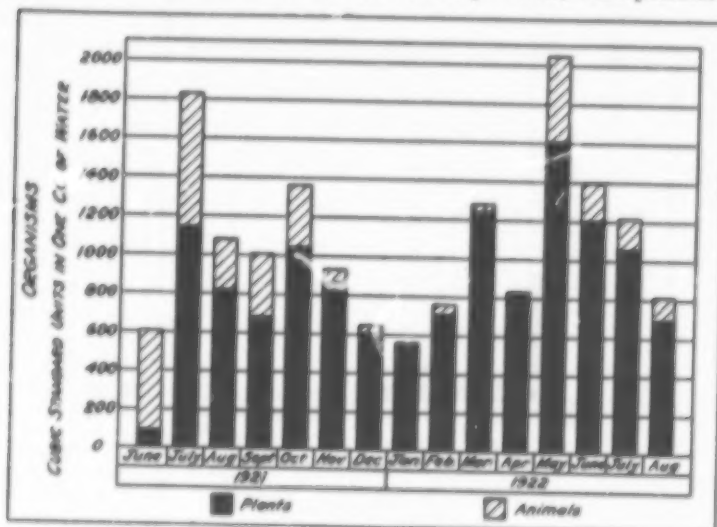


FIGURE 1.—Station 25. Monthly averages of weekly plankton catches expressed as plants and animals

and the remainder were such organisms as are usually found in water known to be relatively clean.

The largest single constituent was, as usual, the green algae, these aggregating 75 per cent of the average total. Diatoms averaged only 7 per cent, as compared to 26 per cent made up by these organisms during the preceding spring months (see Table 48). Flagellates showed some increase, amounting to 6 per cent of the totals, nearly twice the yield of this group during the spring months.

Synedra and *Asterionella* were the leading diatoms, *Pleurococcus*, *Scenedesmus*, *Tetraspora*, and *Actinastrum* the leading green algae. *Cryptomonas*, *Chlamydomonas*, *Euglena* (3 species), and *Trachelomonas* were the prominent flagellates, and *Codonella*, *Tintinnus*, and

Vorticella were the leading ciliates. Rotifers were few in number but these few represented five genera. Crustacea were present in nauplius form only.

In the ciliate contingent, the cleaner-water forms *Codonella* and *Tintinnus* made up over 80 per cent of the total.

Discussion.—Outstanding facts in the situation at station 25 seem to be: (1) Apparent good physical condition of the bottom sediments; (2) large variety of organisms therein; (3) small (relative) numbers of such as are very abundant in the more polluted upper river; (4) relative abundance of such forms as obtain their supply of oxygen by means of gills from the dissolved oxygen of the water

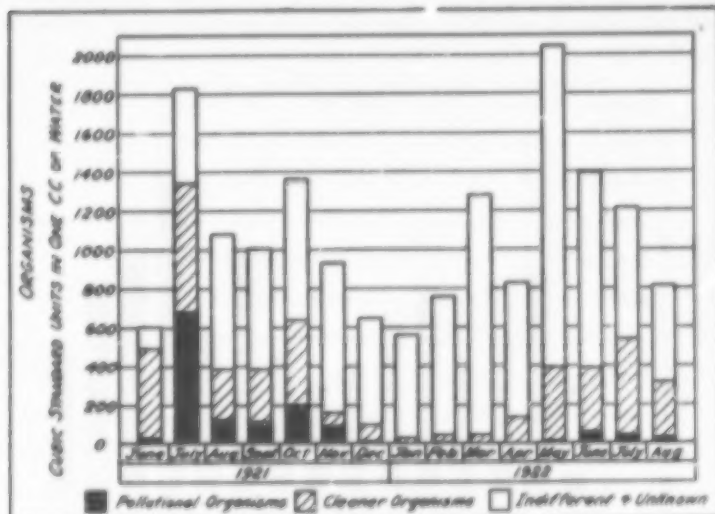


FIGURE 14.—Station 25. Monthly averages of weekly plankton catches: expressed as pollutional, cleaner, and indifferent

(5) variety of organisms in the plankton; (6) reasonably small numbers of distinctly pollutional plankton forms; (7) high percentage of oxygen-producing organisms in the total plankton.

Physical condition of the bottom sediments.—These sediments have no odor except that of ordinary earth. There is no trace of the unpleasant odor prevalent in the sediments at station 179 or of the strong and very repulsive odor of such sediments as were obtainable at station 286. Neither are the sediments soft and sticky, as at 179, but they are distinctly granular in their nature. Occasionally a distinctly tough portion would be found as if a deposit of clay had been encountered by the sampler. The color of sediments was always dark, either gray or nearly black, and this would seem to indicate

that some organic matter was still present. Also a considerable amount of minute plant detritus, fragments of leaves, stems, etc., was practically always present. To the senses there is nothing repulsive in these sediments. They seem clean, indeed, when compared with the sticky, gas-filled, vile-smelling mud always found at station 179.

Variety of organisms in the sediments.—Sixteen different groups of animal life are found in the sediment at station 25. Without attempting refinements, it is known that at least three of these groups have several representatives each. The May flies, for instance, regularly occur in three varieties, the Bryozoa in four, and the Chironomidae in six at least, with others which we could not identify. Contrasted with this list we find, in the sediment at station 179 only six groups of organisms. One of these, the Chironomidae, shows six recognized varieties, with the probable presence of others which we were not able to identify. It seems evident that the gas-filled, odorous sediments at 179 are unable to support the variety of organisms found at station 25, where the sediments are granular rather than spongy, and are without odor.

Pollutional organisms in the sediments.—These are comparatively few in number, consisting chiefly of the tubificid worms. These averaged 13 per liter of mud for the 12 collections taken. Small mussels of the tolerant *Sphaeriidae* averaged 65. No other organisms of known preferment for polluted environment appeared in the sediments at station 25.

The Chironomus larvae taken in these collections were mainly those forms that are found in clean, rather than polluted environment. Out of a total of 264 larvae taken in all samples, 178¹⁶ were identified, and 94 of these, or 53 per cent, were *C. digitatus*, *Procladius concinnus*, and *Tanypus monilis*, all of which are listed¹⁷ as clean-water species by Mr. R. E. Richardson in one of his several careful studies of the Illinois River. It may be further stated that 55 of the total of 264 were *C. flarus*, for which I can find no rating as to its preferred environment. However, judging from the fact that in company with this *C. flarus* there were many *Hydropsyche*¹⁸ (a gill-breathing caddis larvae of well-authenticated clean-water preferment), it is reasonable to suppose that *C. flarus* is of like preferment, or perhaps is indifferent to its environment.

¹⁶ Because of the very large amount of minute plant detritus in most of the sediment samples, it was practically impossible, without unwarranted expenditure of time and energy, to separate these larvae, many of them very small, from all of the mass of detritus, etc., obtained by washing 1 liter of mud through the fine sieve. In many cases only half of this material was taken, and, by the use of a hand lens, all the worms and larvae carefully picked out. It thus happens that only a half or less of the number of larvae present were available for subsequent identification.

¹⁷ Changes in the bottom and shore fauna of the middle Illinois River and its connecting lakes. Bull. Nat. Hist. Survey, Vol. XIV, Art. IV, 1901, pp. 43, 51, 56.

¹⁸ See Table 46, entry of June 15, 1921, Kampsville Dam.

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TABLE No. 49.—Summary of conditions as shown by bottom samples and field observations

Station	Field trips and samples	Period included	Degree of pollution as indicated by—						Summary (per cent)		
			Physical conditions			Biological content			Marked	Light	Doubtful
			Marked	Light	Doubtful	Marked	Light	Doubtful			
292.....	9	September, 1921, to August, 1922.	4	5	-----	3	6	-----	89	61	-----
Des Plaines River	9	do.	-----	-----	9	-----	1	3	-----	8	94
293.....	9	do.	4	5	1	4	4	-----	80	44	6
296.....	9	do.	4	5	-----	-----	-----	-----	87	13	-----
337.....	-----	June, 1921, to September, 1921.	-----	-----	-----	-----	-----	-----	100	-----	-----
179.....	13	June, 1921, to August, 1922.	7	6	-----	5	4	-----	62	35	-----
122.....	11	do.	-----	5	3	-----	7	4	-----	65	33
Spoon River.....	13	do.	-----	-----	13	-----	13	-----	-----	-----	100
100.....	5	June, 1921, to October, 1921.	-----	-----	-----	-----	1	4	-----	10	90
25.....	14	June, 1921, to August, 1922.	-----	-----	14	-----	4	10	-----	14	86

NOTE.—Where samples were not obtainable (on account of rocks, ice, etc.), the field observation as to odor and color of water and the amount and kinds of floating matter has been used as the basis for indicating the approximate condition as to pollution. Of the above total of 96 samples, 17 were in this category.

It is of interest in this connection to compare notes with the situation at station 179, where the strong, unpleasant odor of the gas-filled mud gives physical evidence of pollution. Here the average yield of the thirty-three 1-liter sediment samples taken was nearly 2,200 tubificid worms and 460 *Sphæriidæ*, together with innumerable shells of this tolerant bivalve. A total of 380 *Chironomus* larvæ were taken during the investigation. Of these, somewhat over 300 were examined for identification purposes. The great majority, 247, were a species of *Tanytus* whose exact classification we failed to ascertain, even after dissection of head and examination of labia, mandibles, and antennæ. Of the remainder, 13 were *C. lobiferus*, 16 were *C. decorus*, 27 were *Protenches carneus*, and 5 were *Protenches culiciformis*.

Relative abundance, in the sediments at station 25, of such animal forms as breathe by means of gills.—Aside from the *Chironomus* larvæ, many of which are provided with simple anal gills, and which occurred both at station 25 and at various points upstream as far as station 179, there were other insect larvæ in the sediments at station 25 with more elaborate gill arrangement. These were the May flies, the caddis flies, and the dragon flies, three genera of the first and one each of the second and third. The 42 sediment samples collected yielded a total of 831 of these gill breathers, or an average of about 20 per sample. Meantime the samples taken at station 179 yielded none at all of these forms, not one gill-breathing larva (aside from the

Chironomidae already discussed) being found in the thirty-three 1-liter samples of bottom sediments.

This state of affairs would seem to indicate that the water at this lower station contains sufficient stores of dissolved oxygen to meet the requirements of these gill-breathing insect larvae.

The most abundant organism at station 179 was sludge worms, chiefly *Limnodrilus*, with a few *Tubifex*. These organisms seem able to get along with a very small amount of oxygen, or even in the absence of it, as stated by Birge and Juday.¹⁹ The present writer has kept these worms in small quantities of mud and water exposed to an atmosphere of almost pure hydrogen,²⁰ under which conditions in the laboratory they survived for nearly a week. In another experiment to test longevity of these worms under anaerobic conditions, a half-inch layer of septic mud containing 50 or more worms was placed in the bottom of a 500 cubic centimeter bottle, sewage added, and the bottle closed with air-tight ground-glass stopper, being careful to include no bubble of air. The sewage and mud speedily became dark colored, but at the end of nine days about 20 worms were still living, though not normally active, and somewhat whitish in color. Two worms were still alive at the end of 27 days.

Doctor Forbes and Mr. Richardson found immense numbers of these worms in bottom sludges that contained practically no oxygen. Referring to the ability of the worms to live in such an environment, these investigators say:²¹

Their circulatory system likewise specially adapts them to life in water with a minimum amount of oxygen, the blood containing sufficient hemoglobin in solution to give it a red color and being kept in active circulation through a closed system of blood vessels.

The plankton at station 25—Variety of organisms.—Apparently the same general conditions that affect organisms of the bottom sediments are found to be operative on plankton organisms in the overlying water, for as a rule there is evident correlation as to the kinds and relative numbers of the various forms making up the populations of these two environments. It should be borne in mind, however, that the water is a mobile body subject to continuous mixing and to very frequent exposure to air because of the overturn incident to the flow of the stream over and through a channel which in various sections varies greatly perhaps in width, in depth, and in number of channel obstructions. It seems obvious that such mixing and exposure to air must favor the chemical reactions and to some degree hasten the biological activities that are concerned with the elimination of organic

¹⁹ Inland Lakes of Wisconsin, p. 124.

²⁰ Chemical analysis of atmosphere used showed presence of one-half of 1 per cent of oxygen.

²¹ Studies on the Biology of the Upper Illinois River. Bull. Ill. State Lab. Nat. Hist., Vol. IX, Art. X, p. 512.

matter in the body of water as a whole, because every portion of this body is bound to be subject, sooner or later, to some or all of the physical changes named. No such advantages accrue to the bottom sediments. They are neither mixed nor are they brought into frequent contact with the air. The bottom sediment is merely an accumulation of such suspended matter as has, by reason of its specific gravity, settled to the bottom. Aside from occasional possible removals by floods, this accumulation remains stationary and is continuously augmented by additional material settling out of the overlying water. It is benefited only by such air as it may receive secondhand, so to speak, from the air content of the deeper water in contact with the mud surface.

Handicapped by these disadvantages (as compared with the water) and further burdened by the continuous acquisition of additional suspended matter settling from the overlying water, it would seem reasonable that processes of purification should proceed at a slower rate in the concentrated, motionless, nonaerated bottom sediments than in the relatively dilute, well-mixed, frequently aerated organic matter in the water body proper. Observations recorded by Forbes and Richardson²² indicate that the dissolved oxygen content of the water at Morris was 16.5 per cent of saturation in August, whereas analysis of the gases collected from the bottom sediments showed oxygen virtually absent, while carbon dioxide and methane formed 19 and 79 per cent, respectively, of the gas content, this being essentially the composition of gases usually generated in a septic tank. The slower program of purification in bottom sediments is further indicated by the rank, very repulsive odor such sediments usually exhibit as compared with the moderate or mild odor of the overlying water at the same time and place. This is evident at station 286 and at station 227, while at station 179 the bottom sediments have a strong sewage odor (except in midwinter), but the clear, clean-looking water is without odor even in summer.

While the variety of bottom organisms at station 25 is nearly three times as great as at station 179, there is no similar disparity shown in the plankton organisms, for at the lower station we find a total of 76 species as compared with 80 at station 179. Further up the river at station 227 (La Salle) we find 82 species. It is in this stretch from 227 to 179 that the water loses its sewage odor (but the bottom mud does not). It is to be noted, however, that at station 263 we find 40 species in the plankton and at the uppermost river station (286) there are but 30. This would seem to be in general accord with the statement just made, that purification processes advance more rapidly in water than in the bottom sediments, for the variety of organisms

²² Bull. Ill. State Lab. of Nat. Hist., Vol. IX, Art. X, pp. 511, 514.

in the plankton reaches its larger values as early as station 227, whereas the bottom sediments at station 179, 48 miles below, are still in their low values as to variety. The table herewith given will present these data in condensed form:

Species of organisms represented in the plankton samples and in the bottom sediments of successive Illinois River stations

Sampling stations.....	266	263	227	179	166	122	25
Species in plankton samples.....	30	40	83	80	82	88	76
Species in sediments.....	1	(¹)	1	117	(¹)	26	297

¹ No samples.

Pollutional organisms in the plankton at station 25.—These are relatively few in number. Attention is here directed to Tables 50 and 51, where the winter samples show an average of 5 per cent of pollutional forms in the index organisms, and the summer samples average 25 per cent pollutional forms. Taking all the collections for the 15 calendar months and expressing results in an 11 months' basis (see Table 6), the average of pollutional organisms is 22 per cent.

TABLE NO. 50.—Summary of plankton data in cubic standard units per cubic centimeter, gelatin counts of bacteria per cubic centimeter, and flow data

[Averages for four winter months,¹ December, 1921, January, February, and March, 1922]

Station	Stream flow in thousand second-feet	Mean time of flow from station 266	Cubic standard units per c. c.			Bacteria per c. c. (gelatin)
			Index organisms		Total plankton	
			Total	Per cent pollutional		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
262	8.53		167	45	557	579,260
Des Plaines River at Lock- port	.81		76	45	319	80,680
263	9.3		192	59	463	634,260
264	9.3		173	71	496	634,260
Kankakee River	5.93		48	30	355	25,879
265	16.03	11.9	296	86	670	760,760
267	19.86		306	81	632	361,760
179	20.85	141	106	72	381	74,860
166	20.96	182	56	20	371	30,736
122	21.25	205				26,000
Spoon River	22.66	223	52	44	468	30,830
268	1.13		45	23	661	80,050
269	46.15	260	55	8	807	21,260

¹ The transitional month November is omitted.

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TABLE NO. 51.—Summary of plankton data in cubic standard units per cubic centimeter, gelatin counts of bacteria per cubic centimeter, and flow data

[Averages for summer months¹ common to all stations, June, July, August, and October, 1921, and May, June, July, and August, 1922 (data of June, July, and August for two calendar years averaged)]

Station	Stream flow in thousand second-feet	Mean time of flow from station 286	Plankton, cubic standard units per c. c.			Bacteria per c. c. (gelatin)
			Index organisms		Total plankton	
			Total	Per cent pollutional		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
202.....	8.47	.....	243	51	730	3,314,000
Des Plaines River.....	12	.....	1,476	12	2,853	8,180
286.....	7.06	.....	374	44	771	2,010,000
286.....	8.81	.....	307	60	665	1,570,000
Kankakee River.....	1.90	.....	119	15	360	8,580
263.....	11.44	12.3	458	56	865	738,300
237.....	12.37	38.2	452	54	848	111,780
179.....	14.4	135.3	606	30	1,228	17,360
166.....	14.75	183	855	23	1,551	5,000
148.....	15.1	279.4	908	27	1,848	183,000
122.....	16.30	260.5	297	8	1,261	40,450
Spoon River.....	6	.....	549	25	1,373	30,410
25.....	24.4	308.5	.....	.....	.....	8,170

¹ The transitional month April is omitted.

It seems reasonable to regard the plankton data of the summer months (when practically all organisms are most active) as an adequate criterion of the average effects we may expect from plankton activity. The relatively small yield of the winter months is less dependable because of (1) the small amount; (2) the unstable conditions of water; (3) irregular collections due to field difficulties such as ice, extreme cold, and very high water; (4) difficulty of getting a representative sample in the unstable waters, now swollen by floods from one tributary and now by accessions from a different tributary.

It will also be observed, on inspection of Table No. 51, column 5, that in summer months the percentage of pollutional organisms at station 25 is lower than that of any other main-stream station except station 166, where the percentage is just a trifle lower than at station 25. This does not hold true in the disturbed, uncertain plankton of the winter months (including March), as is seen in Table 50. However, assembling the basic plankton data² according to the calendar months, omitting September, as in Table No. 4; or according to the five calendar seasons represented by the 15 months' investigation, placed on an 11 months' basis, as in Table No. 6, the result is that the percentage of pollutional forms in the index organisms at these two stations is practically identical, being 22 to 25 per cent at both stations.

² Tables 9, 13, 17, 19, 21, and similar tables for each sampling station are given in the summary by stations section. These tables, together with the weekly data given in classification Table No. 54, constitute the source of such summary tables as Nos. 4, 50, 51, and 52.

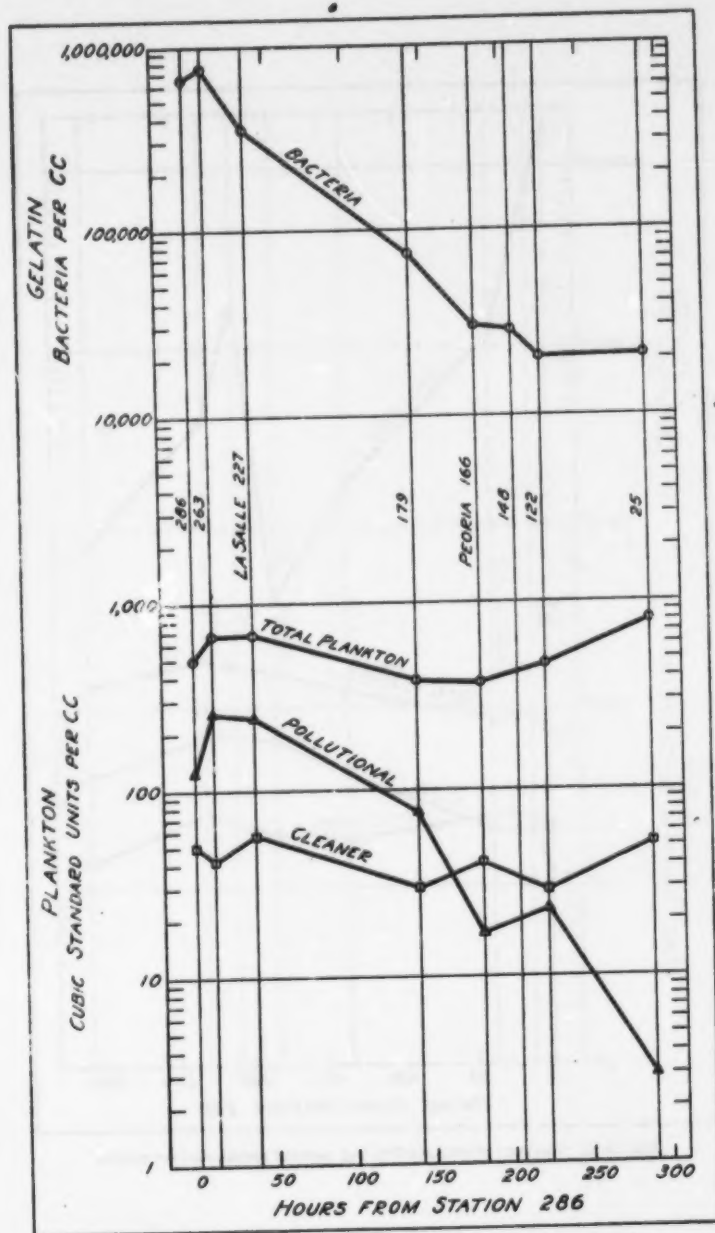


FIGURE 17.—Summary of plankton data and bacterial counts, winter months

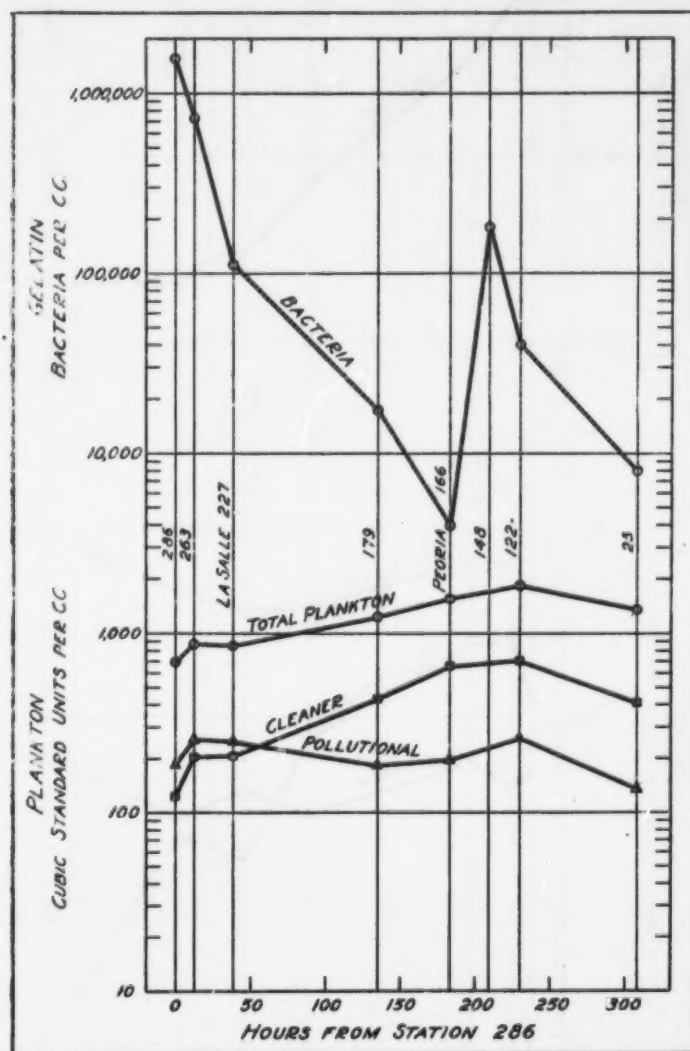


FIGURE 18.—Summary of plankton data and bacterial counts, summer months

It seems worthy of note that the water at these two stations is from the biological point of view very similar in apparent sanitary quality. At the uppermost station the water has had the beneficial effects of a very long time factor during its leisurely passage through the mile-wide expansion known as Peoria Lake. In addition, the water at the foot of the lake must necessarily contain a portion of that water which has been in the shallower widened portions of the lake adjoining the channel proper. Even when levels are stable these waters will mix to some extent, and when levels are falling there is bound to be a considerable drainage from the shallows toward the channel. Some of this water may have been on these shallow areas for many days, perhaps for some weeks, during which time natural purification processes would be active, especially in summer.

The water at the lower point, station 25, has no extensive shallow area or lake for its special benefit. On the contrary, it has, during the intervening flow of 141 miles, received some sewage and waste from Peoria and Pekin, and has received the Sangamon River whose waters, polluted by the sewage and wastes of Springfield, would seem to effect little or no dilution of the relative sewage concentration in the main stream. On the other hand, the unpolluted Spoon River, the small Mackinaw, and Crooked Creek, all relatively clean streams, have presumably counteracted to a greater or less extent the effects of possible pollution in the larger Sangamon. Meantime undoubted benefit accrues to the main stream by reason of a shallow area several square miles in extent located fortunately where the Sangamon must empty into it before its waters join the main stream. The net result of these varied experiences seems to be that the water at station 25 has improved to about the same degree that has resulted from the slow movement through the shallow 18-mile stretch of Peoria Lake.

TABLE NO. 52.—Summary of plankton data in cubic standard units per cubic centimeter, gelatin counts of bacteria per cubic centimeter, and flow data

[Averages for 11 months, October, 1921, to August, 1922]

Station (1)	Stream flow in thousand second- feet (2)	Mean time of flow from sta- tion 286 (3)	Cubic standard units per c. c.			Bacteria per c. c. (gelatin) (7)
			Pollutional (4)	Cleaner (5)	Total plankton (6)	
			<i>Per cent</i>	<i>Per cent</i>		
292.....	8.60	.....	107 51	106 40	687	1,912, 100
288.....	8.60	.....	154 40	186 51	673	1, 146, 790
294.....	9.21	0	153 60	103 40	637	1, 104, 600
263.....	15.46	12.0	276 66	145 34	861	661, 100
227 (La Salle).....	17.73	36.0	179 86	132 43	723	219, 000
196.....	21.14	80.3	142 45	172 55	923	66, 630
179.....	19.97	136	123 36	231 64	793	35, 230
166.....	20.2	178	88 20	260 80	623	15, 015
123 (Havana).....	21.6	222	111 20	446 80	1, 545	28, 192
25.....	22.4	291	30 18	313 84	1, 072	12, 498

¹ This total includes "indifferent" organisms, and also those of unknown sanitary significance.

² For 6 months only.

That this is the real condition of affairs is further indicated by an inspection of the bacterial data of the two stations. Table No. 52 is an attempt to summarize the plankton and bacteria picture presented by the various main-stream stations over the maximum period during which collections were simultaneously taken, October, 1921, to August, 1922, inclusive. This table is essentially a picture of the progressive biological stages of the stream so far as plankton and bacteria are concerned, as the water proceeds from the region of heaviest pollution (stations 292, 288, and 286) to the lower river, station 25, where the physical properties indicate that the stream has nearly or quite recovered from the sewage pollution during this flow, involving a mean time interval of 291 hours and a distance of 261 miles. Inspection of this table or examination of the corresponding graph (fig. 19) reveals again a general similarity of conditions at the two stations, 166 and 25, this similarity being expressed in: (1) The total bacteria (gelatin count); (2) the total plankton; and (3) in pollutional and cleaner plankton, respectively, the former showing a decrease to small content (20 per cent and 16 per cent, respectively, of the total index organisms, columns 4 and 5), and the latter showing reasonably high content of cleaner organisms as compared with upstream stations.

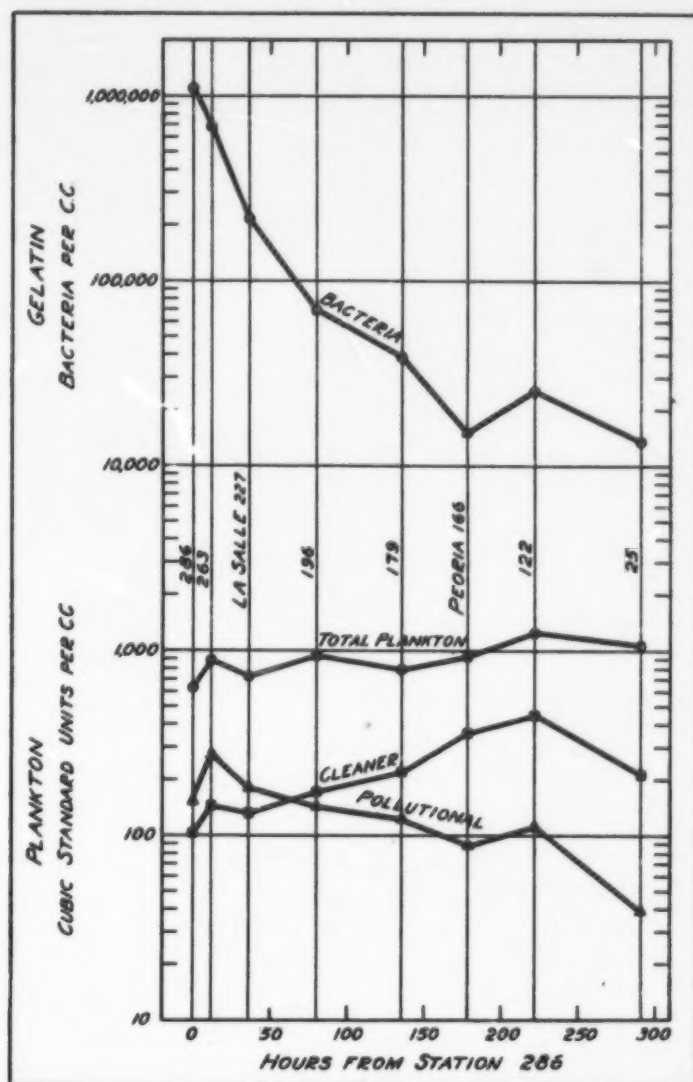


FIGURE 10.—Summary of plankton data and bacterial counts winter and summer. Summary for 11 months; October, 1921, to August, 1922



FIGURE 20.—THE JACKSON STREET DAM AT JOLIET



FIGURE 21.—THE DES PLAINES RIVER AT HIGH WATER. LOOKING UP-
STREAM FROM THE SIXTEENTH STREET BRIDGE AT LOCKPORT

186a



FIGURE 22.—THE TURBULENT WATER AT
STATION 286 (BRANDON BRIDGE)



FIGURE 23.—THE ILLINOIS RIVER AT STATION 179. NOTE EMERGENT SNAGS
IN THE FOREGROUND AND THE WIDENED RIVER BEYOND THE BAR

1866



FIGURE 24.—THE SPOON RIVER. NOTE TRACK LEFT IN THE SURFACE GROWTH ("WATER BLOOM") BY THE MOTOR BOAT

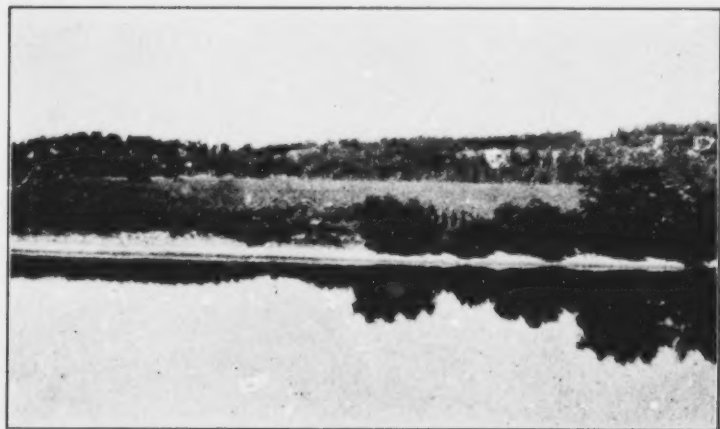


FIGURE 25.—ROCK WALLS BORDERING THE PRESENT FLOOD PLAIN NEAR LA GRANGE

186 c



FIGURE 26.—THE ILLINOIS RIVER DAM AT LA GRANGE

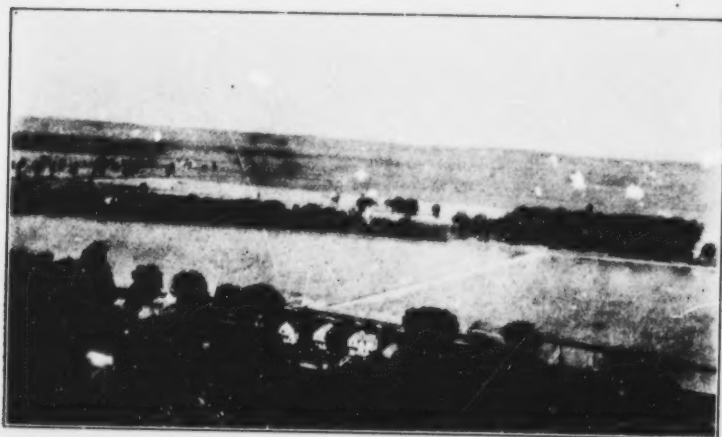


FIGURE 27.—THE ILLINOIS RIVER AT KAMPSVILLE SHOWING DAM, LOCKS IN FOREGROUND AND LEVEE-PROTECTED BOTTOM LAND IN BACKGROUND

186 d



FIGURE 28.—CARCHESIUM, THE COLONIAL CILIATE VERY ABUNDANT IN THE UPPER ILLINOIS RIVER

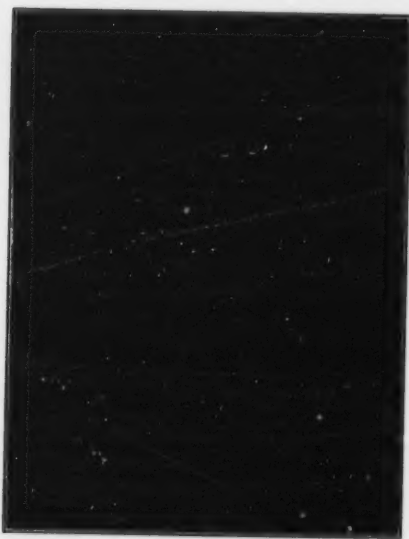


FIGURE 29.—A SMALL PORTION OF CARCHESIUM HIGHLY MAGNIFIED. NOTE THE COILED STALKS

1862

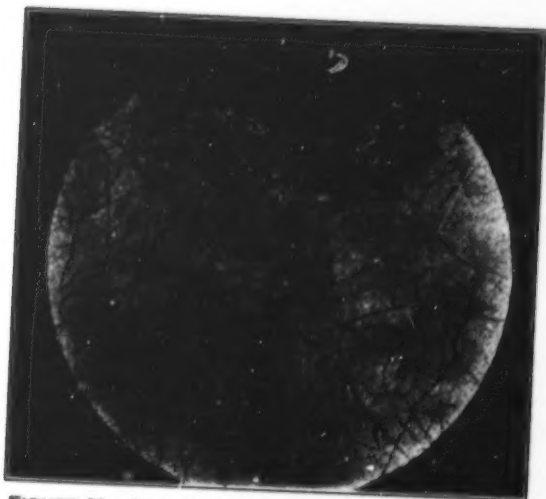


FIGURE 30.—BEGGIATOA (LIVING MATERIAL) A LARGE WHITE SULPHUR-BACTERIUM COMMON IN SEWAGE-POLLUTED WATER

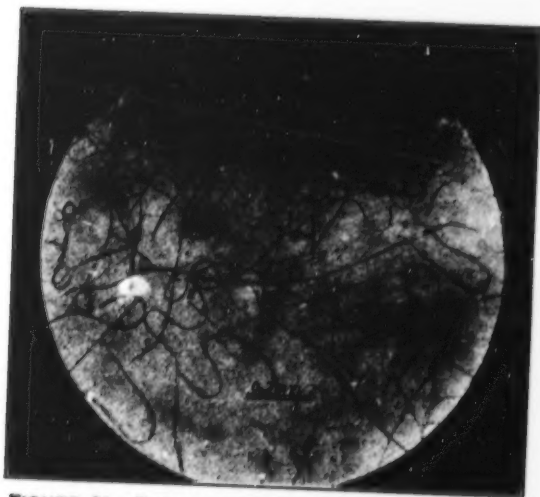


FIGURE 31.—THE SAME FIELD AS IN NO. 30 PHOTOGRAPHED ONE MINUTE LATER TO SHOW SLIGHT MOVEMENT OF THE ORGANISMS MEANTIME. COMPARE REGIONS 1 TO 7, INCLUSIVE, IN EACH FIGURE

186 f



FIGURE 32.—BEGGIATOA HIGHLY MAGNIFIED, SHOWING GRANULAR APPEARANCE DUE TO SULPHUR WITHIN THE ORGANISM

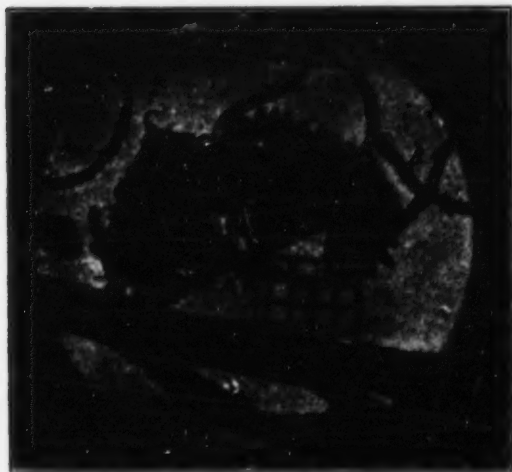


FIGURE 33.—A, COLONY OF EPISTYLIS, OFTEN FOUND WITH CARCHESIUM B, ALGA FILAMENT COVERED WITH SMALLER SCALELIKE ALGA. FROM C TO D IS 1 MILLIMETER

186g

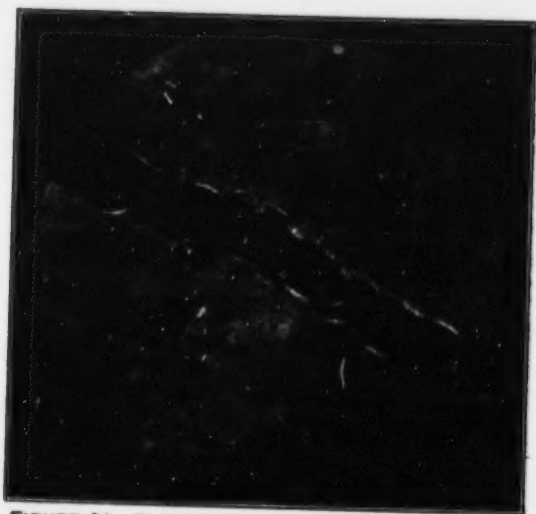


FIGURE 34.—CHAINLIKE APPEARANCE OF ALGA FILAMENT WHEN COVERED BY OVERGROWTH OF A SMALLER SCALELIKE ALGA

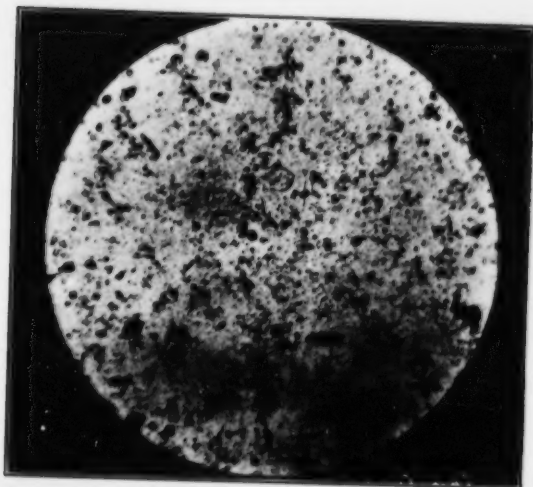


FIGURE 35.—MINUTE FORMS OF PLANT PLANKTON, DES PLAINES RIVER. (USE A READING GLASS)

186 R

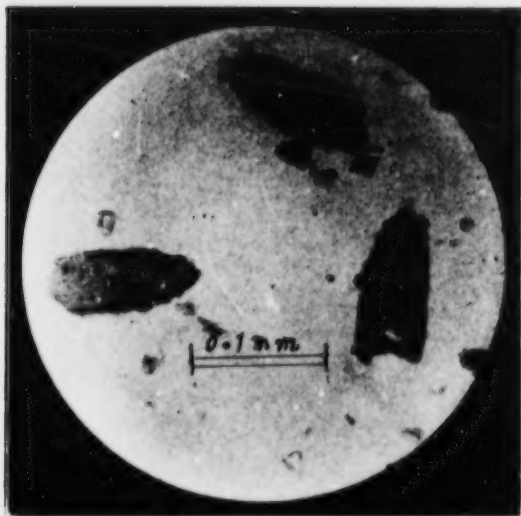


FIGURE 36.—TINTINNUS FREQUENTLY ABUNDANT IN
CLEANER WATER ENVIRONMENT

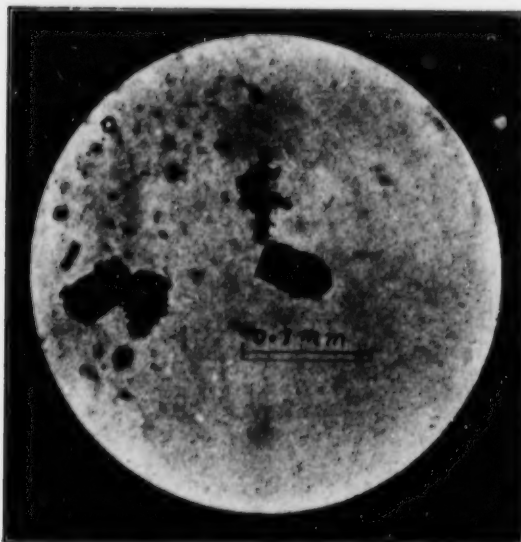


FIGURE 37.—CODONELLA FREQUENTLY ABUNDANT IN
CLEANER WATER ENVIRONMENT

186 i

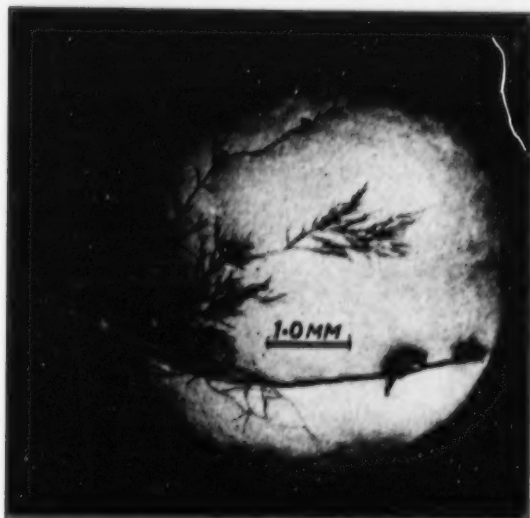


FIGURE 38.—DELICATE GREEN ALGA STIGEOCLONIUM AND A FILAMENT OF THE LARGE CLADOPHORA ABUNDANT IN THE DES PLAINES RIVER

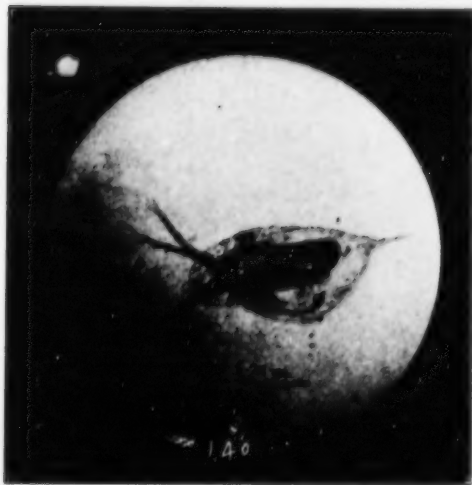


FIGURE 39.—DAPHNIA. ONE OF THE LARGER PLANKTON ORGANISMS

186 8

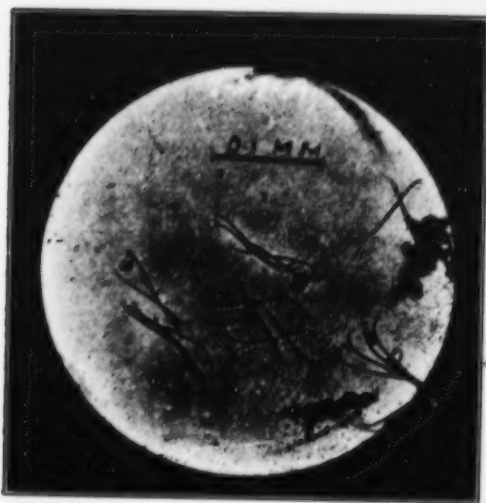


FIGURE 40.—HOOKED AND CLEFT SETAE ("LEGS")
OF TUBIFICID WORMS



FIGURE 41.—EGG CAPSULES OF TUBIFICID WORMS

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FIGURE 42.—CHIRONOMUS LARVAE

APPENDIX A

BRIEF COMPARISON OF THE ILLINOIS RIVER WITH OTHER STREAMS

The Illinois River, made up largely of the dilute sewage from the Chicago Drainage Canal and liberally seeded with a varied plankton by the small Des Plaines River, is thoroughly mixed at the start, chiefly by rapid flow over the steep gradient of the upper reaches, especially in the Joliet region. Subsequent less rapid flow gives opportunity for some sedimentation until about 110 miles below Joliet, on reaching an expanded lakelike portion of its channel, Peoria Lake, the water flows very slowly, spreads over a large area and thereby profits, presumably, from maximum values of sedimentation and of surface exposure as well. Escaping from Peoria Lake, and mildly repolluted meantime by sewage and waste from Peoria and Pekin, the remaining distance (161 miles) of its flow is accomplished without special change or effect traceable to the few small tributaries and the three low dams along the lower reaches.

The Ohio River.—Initial mixing in the Ohio is not so thoroughly accomplished. Instead of a turbulent section where the sewage is introduced at Pittsburgh there is a series of dams at intervals of 5 or 6 miles below the city for 25 miles. The water cascading over these dams is well mixed, but much of the suspended matter settles in the slack water above the dams, thus tending to deposit sludge in large amounts. Moreover, it is a question whether the suspended matter forming this sludge has had sufficient time for adequate biological and chemical action on its organic content. It is possible, however, that the very slow movement of the water above these dams permits adequate time for the more putrescent organic matter to become stabilized as it slowly settles, and that in this way, together with the subsequent very heavy dilution with relatively unpolluted tributaries of large size, the Ohio River begins its process of natural purification on as favorable terms, perhaps, as does the Illinois River, with its thorough and adequate initial mixing of sewage with water, though subsequent dilution of the Illinois River by tributaries below the Kankakee is nearly negligible.

The Potomac River.—The sewage of Washington, D. C., is emptied into the Potomac River 2 or 3 miles below the city. Beginning near this point, the lower 100 miles of the river's length is characterized by numerous shallow expansions of the stream, some of which are a square mile or more in area. These are essentially submerged flood plains, for the lower Potomac lies in a drowned valley, due to the gradual subsidence of the Atlantic seaboard.

The shallow water on these expansions of the Potomac River is thickly populated with a dense growth of submerged green plants. Much of this growth is near the water surface so that when viewed from the deck of a passing steamer these water bodies look like vast level meadows.

Ordinarily the river current would mingle only slightly with these accessory water bodies were it not for the tides. These dominate the situation by raising the water level about 3 feet twice each day and thus forcing the sewage-polluted water of the channel into and through the mass of submerged plants on these aquatic meadows. This compels thorough mixing of sewage with a large volume of water, regenerates the mixture by exposing it to a very large air surface on the

shallow flats, and brings the organic matter of the sewage into intimate contact with water which is rich in oxygen by reason of the activity of the submerged green plants that cover the flats. Meantime twice each day the action is reversed by the ebb tide and the mixed, aerated, and oxygenated sewage and water is drained back into the channel to be forced out on another plant-filled flat farther down the river a few hours later. It would be difficult to imagine a treatment better suited to insure the rapid natural purification of polluted water than is given in these automatic mixing, aerating, oxygenating, sedimentation, and delay stations of the Potomac River. It probably has as thorough mixing of sewage as has the upper Illinois and in a larger body of water. It has more opportunity for sedimentation and settling than has the upper Ohio.¹ Over and above these advantages it further enjoys the great stores of oxygen² given off by the submerged plants.

It is thus that rivers, though somewhat similar as to visible external characteristics, may yet differ to a marked degree in certain factors of the environment which are important in the mechanism of natural purification. While it is true that our present knowledge is incomplete concerning the interrelations and the relative efficiency of these factors, and we must resort to elaborate study of a given stream for actual results, yet, within broad limits, it is even now possible for the experienced observer, after careful inspection of a given stream, and a consideration of its assets and liabilities, to affirm that such stream will be able or will not be able to handle successfully by natural purification a given load of sewage.

¹ Potomac Flushing. Purdy, 1913. Hyg. Lab. Bull. No. 104, p. 174.

² Idem, p. 172.

APPENDIX B

ORGANISMS OTHER THAN PLANKTON

Reference is made to the larger organisms in the bottom mud, or on the bottom, or attached to sticks, stones, or other support along the stream margins, and in some cases on the bottom or at the surface.

Monthly sampling at most of the stations furnishes a fair collection of these larger forms of life that were present during the year. The list includes both plants and animals—the latter more in evidence as a rule—and, in accordance with biological laws, these larger organisms will to a great extent reflect the prevailing conditions of their environment, as do the smaller organisms of the plankton.

The plankton organism, carried about by a given particle or volume of water which surrounds it, must necessarily reflect, as it thrives or fails to thrive, the prevalence of favorable or of unfavorable environment supplied by this water. Certain of the larger organisms have well-developed powers of locomotion and are capable of moving over considerable distances, as fish do, but their range is less extensive. Such organisms may select their environment; finding an unfavorable one, they will move to another, until they find one to their liking, if such be available. Failing to find such environment, these organisms must speedily perish. Crayfish, worms, fish, most insect larvae, water-dwelling beetles and bugs, and certain amphibians constitute these organisms endowed with adequate power of locomotion to enable them to select their environment.

ATTACHED ORGANISMS

Various of the larger organisms have limited powers of locomotion or none at all. Many of the plants are fixed, either by actual roots or by mere "holdfasts." Thus the Potamogetons, eelgrasses, Ceratophyllums, certain fungi, and many of the algae maintain their position, while the water meantime passes by. A few plants, such as lemna (duckweed) and certain of the algae, are unattached and are moved about somewhat by general movements of the water. Such plants, however, usually thrive in water that is nearly or quite motionless.

Cerchersium, and similar forms.—Certain animal forms also are attached to sticks or stones or any convenient support. Prominent among these are the Bryozoa, the sponges, and the Vorticellids. These latter, on account of the small size of the individual monads, are, when detached, classed with the plankton. But under favorable conditions they grow in large fluffy colonies like tufts of cotton and attached along several inches length of grass stems, weeds, strings, sticks, or any kind of convenient support that may be submerged in the current. Such a colony may be 3 to 10 inches long, an inch more or less in diameter, and will contain an enormous number of individuals or "heads" attached to the fungus-like stalks. These colonies may also grow in fluffy masses covering several square inches surface of a stone, a board, or other object that happens to be submerged in heavily polluted rapidly flowing water. The stony bottom of a

¹ A careful count and estimate by the writer, requiring several days, was made of the monads or "heads" in a mass of *Cerchersium* measuring 1 cubic centimeter as it was buoyed up and supported in water. The count totaled over 141,000. A comparatively small colony may contain a million individuals.

highly polluted water in rapid motion or the outfall of a sewer is usually practically covered with a carpet of these and allied organisms.

When these individually minute organisms are thus numerous in large colonies and masses attached in margins or bottom of the stream they are properly recorded in the list of larger organisms or the gross life rather than the plankton. Under conditions of extreme pollution, these masses are sometimes the only animal organisms that can be found in quantity. They are, therefore, regarded as an index of the heavy pollution of the water that characterizes their usual environment.

Algae.—In heavily polluted water algae do not thrive, as a rule, especially if the pollution be recent. In the Joliet region the recent origin of the Chicago sewage, together with the turbulence of the water, present a combination that seems unfavorable for nearly all filamentous algae. Two kinds, however, are able to maintain their hold in the current and meantime seem to thrive in the comparatively fresh sewage. These are *Oscillatoria*, a blue-green, and *Stigeoclonium*, a green alga, respectively. The former grows in a feltlike mat covering many of the stones along margins and in an occasional shallow portion of the stream. The latter is attached to sticks or stones near the surface or where water is shallow and trails its bright-green profusely branched body in the current, breaking off occasionally and floating down stream. Many times this green alga was found in the upper river growing on the same support with a white mass of *Carchesium* or of *Sphaerotilus*.

Cladophora.—This is an attached, profusely branched green alga and is exceedingly abundant in the Des Plaines River at Lockport before the drainage canal is turned into its channel. This alga is the most conspicuous feature of the shallow stream here during the summer. It is attached to stones on the bottom or those protruding from shallow water, as at margins. Most of the bottom is obscured from view and about all one can see is masses of this green alga trailing in the current and covering everything in sight. The clear and shallow water, together with these great masses of green alga, constitute an ideal mechanism for production of oxygen by photosynthesis.

Cladophora was found only occasionally and in small amounts in the turbulent, heavily polluted section of the river just below the mouth of the drainage canal. The rapid flow of water here provided one essential factor of its preferred habitat, but apparently the heavy pollution by recent sewage was an unfavorable factor. Aside from occasional tufts of the alga torn loose from some point upstream and floating in the current, *Cladophora* was not found in noticeable amounts until station 179 was reached, where it was found growing in moderate quantity.

UNATTACHED FORMS IN THE BOTTOM SEDIMENTS

Bottom sediments consist largely of the minute material that formerly constituted much of the "suspended matter" of the water. Having at such time formed essentially a part of the water and being continuously deposited from it, the bottom sediments represent an accumulation of evidence, as it were, with regard to the prevalent condition of the water from which this sediment is deposited. These accumulated sediments do not fluctuate in character as widely nor as suddenly as does the water above them; hence such sediments furnish an index of the average condition of the water, and the evidence thus obtained is in substantial agreement with that furnished by a representative series of samples of the plankton, for the worms, insect larvæ, mollusks, or other organisms that find suitable environment in these bottom sediments exhibit some-

² *Biology of the Upper Illinois River*. Forbes and Richardson (1915), p. 510. Bull. Ill. State Lab. Nat. Hist., Vol. IX, Art. X.

thing of the same attitude toward sewage pollution¹—preference for it, or avoidance of it, or indifference—that we find in the plankton organisms. Moreover, the physical conditions, especially odor and pastiness, shown by the sediments are usually in accord with the sanitary status as indicated by the presence of certain organisms in the plankton and by the larger organisms in the mud as well.

Tubificidae.—Of the larger organisms which find their optimum environment in conditions of heavy pollution, the *Tubificidae* seem to hold first place. These worms may be found in great numbers in mud which is nearly or quite septic and in varying numbers as mud and water become improved in sanitary condition. They occur "on the muddy bottom in colonies as red patches which vary from 3 to 12 inches in diameter and contain countless individuals."² Depth of water seems to be no special factor. I have found them in large numbers at depths ranging from a few inches in small sewage-polluted streams, to a depth of 30 feet in the channel of the Potomac River just below the outfall of Washington sewage, and at a depth of 25 feet at station 179 in the Illinois River, where they were found in very large numbers.³ Birge and Juday⁴ found these worms in Lake Mendota at a depth of about 40 feet apparently flourishing under anaerobic conditions. It seems evident that these worms are well adapted for work under conditions of heavy pollution and also under other conditions of partial or entire absence of oxygen, such conditions as could not be survived by any other known organism of equal size, energy, and general efficiency in the disposal of organic matter.

The writer has had unusual opportunity for observing these worms in the field and studying them in the laboratory. The following items of interest have been noted:

1. *Preferred habitat*.—These worms are found in mud that is foul with organic matter, is usually black, pasty, gaseous, and with a vile odor. The highest number I have thus far found in 1 liter of such mud is over 30,000. (See Table 36.) If the quantity of mud be limited, as in a tank or vessel in the laboratory, the worms will decrease in numbers as the mud is worked over and its organic content thereby reduced. In an experiment by the writer a small mass of fecal matter of human origin, buried under such partly exhausted mud in a laboratory culture was discovered within a few hours by the worms. They migrated from various parts of the container and congregated at the spot where the fecal matter was buried.

2. *How they work*.—The worm, about 1.5 inches long when contracted, but 3 to 5 inches when extended, burrows and forages beneath the mud surface, but the posterior third or less of its body is elevated above the mud surface and is usually waving back and forth. The worm seems to eat almost continuously. Observations during 21 hours of the 24 showed no perceptible decrease in its foraging activities, as measured by the fecal pellets which are discharged at about 4-minute intervals from the anal end as it waves back and forth. The average length of fecal material discharged each time is about one-fourth inch. On a conservative basis, supposing the worm to work only three-fourths of the time, the above rate results in the evacuation of a string of fecal pellets about 68 inches in length in 24 hours for each worm.

3. *Results of work*.—The fecal pellets of these worms are decidedly granular, as compared with the pasty condition of the original mud in which the worms

¹ The Plankton and Related Organisms (Ohio River). Purdy (1923), p. 51; also Charts 18, 19, and 20 Pub. H. Bulletin No. 131.

² Studies on Digestion of a Sewage-filter Effluent. Weston and Turner (1917), p. 48.

³ See Table 36.

⁴ Inland Lakes. Dissolved Gases. Wisconsin Geol. and Nat. Hist. Survey. Bull. XXII, p. 134.

were foraging. An incubation test of 24 hours showed an oxygen demand of 2.8 parts per million by these pellets, whereas the original mud beneath the surface showed a demand of 6.7 parts per million. If the mud surface be lightly covered with powdered chalk, this will in turn be entirely hidden in a few hours by the freshly cast fecal pellets. Thus the worms are operating to effect a continuous overturn of the pasty mud and are meantime depositing a new surface layer in the form of minute granular pellets with lowered oxygen demand.

The extent of surface on these fecal pellets is probably significant. Careful measurement of about 40 average pellets shows a total area of 26.7 square millimeters. The total volume of these same pellets is 1.03 cubic millimeter. The mud was ingested by the worms below the surface; hence it then had, strictly speaking, no surface exposed to the flowing water. It seems obvious that in the form of fecal pellets the very large total surface now exposed to the flowing water must possess a far more effective method of purification than was possible when this same mud lay in a mass an inch or more beneath the mud surface.

4. *Effects of low temperature.*—It was observed in laboratory cultures that on the approach of low temperature (near the freezing point) the worms decreased their activity but did not cease it. This is further indicated by a field collection made January 18, 1922, at station 179 on the Illinois River when the water was practically sealed down by ice. By use of a duck boat an opening about 250 feet from shore was approached and mud samples secured. Tubificid worms were numerous in this sample and their digestive tracts were as well filled as were those of like worms taken at the same place the following April.

Sphaeriids.—These small mussels are often very numerous in water which is moderately polluted; thus they are often to be found with Tubificids. However, they can not stand the extreme conditions that the worms can; hence will die out when oxygen becomes largely depleted. Apparently their large numbers in places where water is polluted is a question of their abundant food supply of microscopic organisms normally found there.

A small stream studied by Baker¹ with special reference to the effect of sewage pollution on mollusks, gives some pertinent data. The author says in regard to certain bivalve mollusks: "The distribution of the *Sphaeriids* * * * is interesting and significant in connection with the sewage pollution of the stream * * * no *Sphaeriids* were found * * * between the Urbana ditch and * * * 14 miles below Urbana." These mussels are characteristic mud dwellers, and their absence from the intervening territory in the stream is striking evidence of the unfavorable conditions on the bottom."

Observations by the same author on the snail fauna of the Genesee River, N. Y. (see abstracts) is to the effect that certain water-breathing snails are also adversely affected by sewage pollution, though less sensitive than the bivalves mentioned above. Certain other snails which, though living in water, come to the water surface for air (the air breathers) are naturally much more tolerant of pollution, but even these are not indifferent, as shown by the fact that while the water breathers *Musculium* and *Bythinia* succumbed in five years to the increasing pollution, the air breathers, *Physa*, *Planorbis*, and *Galba*, did not disappear until the eighth year.

Chironomus larvæ.—These are to be found in muds and sediments of all degrees of contamination with the possible exception of the extremely vile habitat capable of being endured by the tubificids. The various species of Chironomids, however, may represent a similar variety in habitat, because they tolerate, to different

¹ The Molluscan Fauna of the Big Vermilion River, Ill., E. C. Baker (1922). Illinois Biol. Monographs Vol. VII, No. 2, p. 20.

² This section is very heavily polluted.

degrees, the presence of sewage pollution. Thus Richardson, in his several investigations of the Illinois River has recorded certain species of chironomid larvae that have been driven out by the increasing pollution of the river and certain other species that still remain and are therefore tolerant of a polluted environment. His classification⁹ is essentially as follows:

1. Pollutants or tolerant species:

Chironomus plumosus L.

Chironomus maturus Joh.

Chironomus frequens Joh.

2. Tolerant or indifferent species:

Chironomus decorus Joh.

Chironomus crassicaudatus Mall.

Chironomus lobiferus Say.

Chironomus viridicollis v. d. W.

Tanytus dyari Coq.

3. Cleaner water species, or of doubtful position:

Chironomus nigricans Joh.

Chironomus tentans F.

Chironomus ferrugineovittatus Zett.

Chironomus modestus Say.

Chironomus dux Joh.

Chironomus digitatus Mall.

Cricotopus sp.

Cricotopus trifasciatus Panz.

Orthocladus sp.

Palpomyia longipennis Lw.

Procladius concinnus Coq.

Tanytus illinoensis Mall.

Tanytus monilis L.

The above list is incomplete, as there are scores of chironomid larvae whose reaction toward sewage pollution could not be observed by Mr. Richardson because they did not appear at all in the collection, or in some cases their position relative to sewage pollution could not be ascertained satisfactorily. As a class the Chironomid larvae seem to prefer relatively clean water, as is indicated by Prof. J. R. Malloch, an acknowledged authority on the subject of Chironomids, who says:¹⁰ "When therefore we discover that the *Chironomids* occur in markedly decreasing numbers as we near the outlet of the Chicago Drainage Canal, where under natural conditions insect life should be as abundant as elsewhere on the river (Illinois), it is an unavoidable conclusion that the comparative absence of these larvae is an indication that the water is unsuited to their requirements."

* * * "From the fact that out of probably 100 species of *Chironomids* that may be found in various portions of the lower Illinois not over a dozen are met with in the portion between DePue and Morris, it is * * * clearly evident that the influx of sewage matter from the drainage canal * * * very seriously reduces the number of these insects normal to the river."

Professor Malloch has found chironomid larvae abundant in the reservoir¹¹ of clean water used for drinking by the town of Champaign, Ill. The writer

⁹ Changes in the Bottom and Shore Fauna of Middle Illinois River and Connecting Lakes, etc. Richardson (1921). Bull. Ill. Nat. Hist. Survey, Vol. XIV, Art. IV, pp. 42, 51, 56.

¹⁰ The Chironomidae, or Midges, of Illinois. By John R. Malloch (1915), Bull. Ill. State Lab. Nat. Hist., Vol. X.

¹¹ Idem, p. 450.

has found them abundant in the clean water of rice fields in Arkansas and California, this water being pumped from deep wells a quarter of a mile distant, or in one case diverted from the upper, turbulent, unpolluted Sacramento River. Chironomids are also common in ditches and puddles adjacent to such rice fields. They may occur to some extent under practically all conditions of environment, whether the water be clean or otherwise, for, as shown by Richardson, a few species are tolerant of sewage pollution or are indifferent to it, while many other species are effectively banished or killed by such pollution.

Other forms.—There are many other organisms to be found in much the same environments that Chironomids inhabit, but so far as present knowledge goes, practically all these forms are confined to the cleaner water, instead of certain species being tolerant of sewage or indifferent to it, as we find in the Chironomids. The list includes the larvæ of the May flies, the caddis flies, stone flies, dragon flies, and damsel flies; also certain of the leeches, of the planarians and certain crustacea (notably crayfish and scuds), and the bryozoa. Certain beetles and bugs, the whirligig beetle (*Dinutes*), diving beetles (*Dytiscus* and *Hydrophilus*), water boatmen and back swimmers, while common in clean water, may also be abundant in polluted water at times. They are to some extent indifferent to pollution by reason of the fact that they come to the surface for air. Presence of these air breathers is therefore not necessarily an indication that the water is clean.

APPENDIX C

(Tables 53 and 54)

TABLE No. 53.—Summary of plankton findings at all stations each month

AVERAGES FOR JUNE, 1921

Sampling stations	Total organisms					Index organisms		Amorphous matter
	Volume, cubic standard units per c. c.	Per cent classed as—				Volume, cubic standard units per c. c.	Per cent classed as pollutional	
		Plants	Animals	Oxygen producers	Oxygen consumers			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
122.....	1,560	49	51	65	35	623	38	60,000
Spoon River (121).....	1,064	97	3	96	4	71	6	520,000
160.....	886	43	57	64	36	713	26	70,000
Sangamon River (99).....	1,305	63	36	90	10	1,305	34	70,000
26.....	868	16	84	26	73	486	6	175,000

AVERAGES FOR JULY, 1921

La Salle (127).....	908	75	24	79	21	890	43	8,000
179.....	1,974	68	17	94	4	1,050	23	11,000
162.....	1,851	88	43	73	27	1,746	37	15,700
122.....	1,900	74	26	83	17	1,186	46	70,100
Spoon River (121).....	1,016	83	16	96	7	190	36	143,000
160.....	1,264	69	31	81	19	823	63	85,000
Sangamon River (99).....	1,671	37	13	97	3	1,220	27	86,000
26.....	1,526	63	37	73	27	1,526	50	85,000

AVERAGES FOR AUGUST, 1921

La Salle (127).....	716	78	22	80	20	390	54	7,700
179.....	950	75	25	88	14	533	36	18,400
162.....	1,306	86	14	94	6	873	16	32,000
122.....	1,768	73	27	76	23	1,043	45	60,000
Spoon River (121).....	1,303	91	9	99	1	176	7	200,000
160.....	787	86	14	85	15	806	45	100,000
Sangamon River (99).....	1,174	91	9	96	3	916	23	136,100
26.....	1,076	76	24	88	12	305	31	87,100

AVERAGES FOR SEPTEMBER, 1921

La Salle (127).....	1,183	85	15	88	12	400	45	11,500
179.....	711	88	14	93	7	307	35	14,600
Mooreville (173).....	1,140	76	23	93	7	487	26	16,100
160.....	941	60	31	84	16	333	23	16,000
122.....	843	86	13	77	23	606	26	84,000
Spoon River (121).....	1,226	96	4	97	3	41	68	304,000
160.....	1,184	79	21	83	18	521	26	21,600
Sangamon River (99).....	1,530	80	20	94	6	670	36	76,400
26.....	1,068	68	33	75	26	394	39	304,500

Column 2—column 7—quantity of organisms classed as "Indifferent and unknown" as to index value.

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TABLE No. 53.—Summary of plankton findings at all stations each month—Contd.

AVERAGES FOR OCTOBER, 1921

Sampling stations	Total organisms					Index organisms		Amor- phous matter
	Volume, cubic standard units per c. c.	Per cent classed as—				Volume, cubic standard units per c. c.	Per cent classed as pollu- tional	
		Plants	Anim- als	Oxygen pro- ducers	Oxygen con- sumers			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
202.....	819	66	34	66	32	363	46	12,000
Des Plaines River (202).....	2,312	94	16	94	6	1,370	12	22,300
206.....	1,182	77	23	78	22	730	26	9,700
208.....	961	85	15	87	13	601	31	11,000
Kankakee River (273).....	363	83	17	93	6	45	43	5,000
209.....	1,090	63	37	64	36	1,233	46	12,500
La Salle (227).....	1,122	61	39	64	36	739	31	13,900
179.....	623	87	13	89	11	300	33	16,700
Mossville (172).....	735	84	16	93	6	361	34	9,300
166.....	1,015	87	13	96	4	490	35	20,000
132.....	999	89	11	97	3	353	36	26,000
Spoon River (131).....	1,310	94	6	97	3	114	0	270,300
100.....	1,008	91	10	96	13	471	16	43,000
Samtamen River (96).....	1,091	83	16	96	4	642	30	74,500
25.....	1,300	77	23	90	10	633	31	66,100

AVERAGES FOR NOVEMBER, 1921

202.....	709	73	27	73	27	905	46	21,000
Des Plaines River (202).....	300	87	13	91	9	140	40	17,000
206.....	910	84	16	87	13	490	40	18,100
208.....	774	83	17	84	16	500	33	22,300
Kankakee River (273).....	367	91	9	96	5	27	27	26,900
209.....	1,407	80	41	87	43	806	63	31,000
La Salle (227).....	734	80	20	84	16	326	41	20,300
179.....	674	87	13	98	7	267	37	31,400
Mossville (172).....	698	95	5	95	5	344	30	17,700
166.....	506	86	13	94	6	213	7	17,900
132.....	706	90	10	96	4	304	8	26,000
Spoon River (131).....	1,009	95	5	96	4	90	9	186,000
100.....	908	94	6	98	2	190	17	11,900
106.....	1,105	90	10	99	1	626	9	35,300
25.....	938	93	7	96	5	159	56	66,300

AVERAGES FOR DECEMBER, 1921

202.....	643	88	12	86	13	227	40	27,000
Des Plaines River (202).....	257	90	10	97	3	45	44	10,100
206.....	544	83	18	80	30	208	39	20,400
208.....	685	89	11	87	13	107	56	30,200
Kankakee River (273).....	370	90	10	99	1	29	48	9,100
209.....	632	84	46	84	46	323	58	26,700
La Salle (227).....	899	49	51	53	46	421	53	33,900
179.....	335	72	28	77	23	55	53	32,100
166.....	354	96	7	96	3	73	14	20,000
132.....	483	91	9	94	6	65	30	16,100
Spoon River (131).....	515	98	7	97	3	53	0	46,400
25.....	643	94	6	96	3	99	8	62,100

AVERAGES FOR JANUARY, 1922

202.....	381	81	19	79	31	118	33	11,000
Des Plaines River (202).....	119	94	14	91	9	34	30	7,400
206.....	409	83	17	74	26	178	33	12,800
208.....	431	87	23	80	41	186	73	18,300
Kankakee River (273).....	86	87	13	87	13	0	0	0,100
209.....	486	67	33	68	37	106	77	16,000
La Salle (227).....	481	81	19	79	21	205	77	17,900
179.....	303	73	27	73	27	86	67	13,300
166.....	286	83	17	89	11	55	40	14,300
132.....	319	83	17	85	15	39	66	10,000
Spoon River (131).....	414	91	9	96	4	46	40	20,900
25.....	555	96	4	98	5	30	0	207,400

Column 2—column 7—quantity of organisms classed as "Indifferent and unknown" as to index value.

TABLE No. 53.—Summary of plankton findings at all stations each month—Contd.

AVERAGES FOR FEBRUARY, 1923

Sampling stations	Total organisms					Index organisms		Amorphous matter
	Volume, cubic standard units per c. c.	Per cent classed as—				Volume, cubic standard units per c. c.	Per cent classed as polychaeta	
		Plants	Animals	Oxygen producers	Oxygen consumers			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
202.....	435	88	17	78	33	143	41	11,400
Des Plaines River (202).....	395	74	26	77	33	140	46	6,000
203.....	344	78	33	71	39	160	73	9,000
204.....	336	80	30	49	51	157	79	10,000
Kankakee River (273).....	438	84	16	95	5	99	27	20,000
205.....	491	69	31	81	39	200	86	7,000
La Salle (227).....	682	55	45	84	46	209	79	34,700
179.....	430	71	29	73	37	137	84	13,000
180.....	375	99	10	91	9	86	26	13,000
122.....	473	85	15	85	15	47	79	25,000
Spoon River (121).....	791	91	9	98	7	45	11	143,000
26.....	783	94	6	98	7	45	4	79,000

AVERAGES FOR MARCH, 1923

202.....	770	98	4	98	7	183	39	17,400
Des Plaines River (202).....	631	88	12	94	6	95	44	49,000
203.....	653	77	23	78	23	218	72	14,000
204.....	649	74	26	73	26	203	76	16,000
Kankakee River (273).....	637	98	7	94	6	74	36	37,000
205.....	1,100	87	43	88	43	494	88	36,000
La Salle (227).....	655	73	27	73	26	294	84	85,000
194.....	461	83	8	98	7	47	6	34,000
179.....	664	74	26	77	23	128	73	29,700
180.....	669	93	6	92	8	45	25	42,700
122.....	718	89	14	89	11	67	39	26,100
Spoon River (121).....	623	87	13	90	11	34	60	280,000
26.....	1,377	97	3	96	3	46	9	285,000

AVERAGES FOR APRIL, 1923

202.....	808	89	11	99	10	190	87	31,100
Des Plaines River (202).....	383	81	19	85	15	130	84	33,000
203.....	798	71	29	71	29	293	79	36,000
204.....	760	80	20	87	13	163	79	26,700
Kankakee River (273).....	673	83	36	66	34	139	65	125,000
205.....	1,233	73	27	71	29	254	75	95,700
La Salle (227).....	438	83	8	94	5	43	19	123,000
194.....	653	74	26	77	23	107	86	41,000
179.....	430	78	24	79	21	100	83	57,000
180.....	635	86	14	91	9	93	4	25,000
122.....	779	92	8	92	8	49	0	46,000
Spoon River (121).....	533	92	8	97	3	33	4	37,000
26.....	533	98	2	96	5	135	9	81,000

AVERAGES FOR MAY, 1923

202.....	1,413	91	9	91	9	234	85	9,400
Des Plaines River (202).....	2,125	83	18	91	9	1,336	15	15,100
203.....	1,066	69	31	71	29	693	55	13,100
204.....	980	78	22	60	20	206	62	15,000
Kankakee River (273).....	413	83	18	83	15	110	86	30,300
205.....	861	66	34	71	29	351	71	13,000
La Salle (227).....	904	63	36	65	35	294	94	23,000
194.....	923	73	27	79	21	285	33	25,000
179.....	1,064	67	33	83	18	730	18	23,000
180.....	1,398	57	43	78	22	662	21	18,000
122.....	2,023	75	25	93	7	773	10	15,000
Spoon River (121).....	634	84	16	97	3	219	0	74,000
26.....	2,045	78	22	83	17	267	3	31,900

Column 3—column 7—quantity of organisms classed as "Indifferent and unknown" as to index value.

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TABLE No. 53.—Summary of plankton findings at all stations each month—Contd.
AVERAGES FOR JUNE, 1922

Sampling stations	Total organisms				Index organisms		Amor- phous matter	
	Volume, cubic standard units per s. c.	Per cent classed as—			Volume, cubic standard units per s. c.	Per cent classed as [Indiferent]		
		Plants	Animals	Oxygen pro- ducers				Oxygen con- sumers
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
202.....	688	72	26	72	26	180	81	26,400
Des Plaines River (202).....	3,074	66	34	75	25	1,080	12	37,400
204.....	806	73	27	76	24	191	29	16,700
206.....	543	66	34	70	30	186	79	16,700
Kankakee River (273).....	616	87	13	83	3	202	7	14,300
208.....	557	81	19	78	22	227	60	15,600
La Salle (227).....	682	82	18	83	17	270	41	12,700
194.....	1,208	66	34	69	31	406	81	19,400
179.....	1,119	60	40	77	23	509	26	15,700
164.....	1,227	53	46	77	23	680	19	16,600
123.....	1,675	65	35	87	13	1,036	11	26,200
Spoon River (131).....	775	83	17	86	5	162	14	21,400
21.....	1,394	86	14	91	9	288	14	24,600

AVERAGES FOR JULY, 1922

202.....	625	90	10	90	10	244	38	14,300
Des Plaines River (202).....	3,001	81	19	91	9	1,901	10	26,500
204.....	551	75	25	74	26	182	44	15,200
206.....	516	68	32	73	27	142	68	12,200
Kankakee River (273).....	86	85	15	85	15	13	0	8,000
208.....	682	86	14	75	25	226	55	10,100
La Salle (227).....	771	74	26	84	16	409	45	8,400
194.....	906	87	13	93	7	386	34	26,400
179.....	1,010	80	20	89	11	433	21	16,400
164.....	1,000	79	21	94	6	567	12	27,700
123.....	2,465	77	23	94	6	1,230	21	26,200
Spoon River (131).....	2,444	68	7	99.6	0.4	1,414	6.14	722,200
21.....	1,211	37	13	93	8	523	8	100,000

AVERAGES FOR AUGUST, 1922

202.....	360	89	11	89	11	163	63	12,400
Des Plaines River (202).....	2,732	75	25	84	16	1,496	10	21,100
204.....	553	64	36	71	29	274	67	9,700
206.....	496	64	36	68	32	272	67	12,300
Kankakee River (273).....	262	93	7	95	5	175	6	8,300
208.....	527	67	33	77	23	214	70	9,700
La Salle (227).....	573	78	22	77	23	311	26	6,000
194.....	1,414	81	19	85	15	441	60	27,400
179.....	1,714	76	24	31	9	1,083	45	15,900
164.....	2,280	71	29	91	9	1,637	23	26,500
123.....	2,963	73	27	89	11	2,213	26	21,900
Spoon River (131).....	1,221	84	16	96	4	288	26	20,400
21.....	510	86	14	92	8	317	8	26,600

Column 2—column 7—quantity of organisms classed as "Indifferent and unknown" as to index value.

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples

STATION 22											
Date	Plankton organisms (in cubic standard units) in l. c. of water										
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Fleas	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1921											
Sept. 25	50	140	180			60	94	20	70		554
Oct. 2	12	214	300			60	105	20	25	27	657
Oct. 12	200		180			15	225			15	625
Oct. 19	180	30	540				195		115		1,065
Oct. 26	10	10	600				175	5		11	672
Nov. 2	120	24	672	20			207		1		944
Nov. 9	600		600			1	60		60		1,261
Nov. 16	10		212	10			22		95	3	451
Nov. 23	10		284				170			64	619
Nov. 30	600	140	481	50		20	60			1	1,264
Dec. 7			120		5		27			10	190
Dec. 14		110	600		20	20					820
Dec. 21			150				90			10	350
Dec. 28	50										50
1922											
Jan. 4	50		247	20			50				370
Jan. 11	50	25	140	24	4	5	14				256
Jan. 18	70	100	261		2	10	45	5		14	494
Jan. 25		60	113				127			10	309
Feb. 1	20		287				73			25	457
Feb. 8	40	60	240			20				10	420
Feb. 15	20		220	11		20				11	300
Feb. 22	120	40	200	90			14	5		21	507
Mar. 1	91	91	273				11	6			472
Mar. 8	4	90	80		23	27	14	5			206
Mar. 15	200	10	240	60			21				531
Mar. 22	500	64	126	65			22				1,129
Mar. 29	1,264	23	60	65			5	2			1,459
Apr. 5	520	67	240	60			20				1,047
Apr. 12			420				40			40	500
Apr. 19	60	13	234				10	5			312
Apr. 26	671		110			12	70				871
May 3	1,400		423	13	2	20	70				2,100
May 10	2,405		242				24	43			2,690
May 17	273	23	600				110	5			1,010
May 24	145	120	220				27			25	517
May 31	98	55	190				180	1			464
June 7	75	55	242				15	13		20	425
June 14		11	145				34	13			200
June 21		7	64				3	1		14	268
June 28	120	64	415				277		60	44	1,079
July 5	224	90	180	10		23	6				534
July 12	200	20	242	20		10	3				705
July 19	176	81	265			34	47			100	667
July 26		76	415				10				506
Aug. 2	9	45	60		5	65	7				126
Aug. 9	15	27	60	15			20	5		10	162
Aug. 16	20	111	200		4	11	20	15		25	341
Aug. 23	15	100	245	55		11	24	15		1	510
Aug. 30		25	124	3		20	43	25		3	200

STATION DES FLAINES

1921											
Sept. 25	200	60	8,000			600	12	75	4		10,551
Oct. 2	245	16	8,121			620	70	110	60	27	4,278
Oct. 12	60	24	1,116			102	72	7	6	3	1,260
Oct. 19	224		2,940	12	12	157	16	5	141	1	2,530
Oct. 26	60		400		21	46	9		15		600
Nov. 2	23	23	445			16	164				672
Nov. 9	22	165	242			11		1			411
Nov. 16		70	190			20		2			210
Nov. 23		60	120							20	241
Nov. 30		90	195			64					270
Dec. 7	22	22	222			11				10	260
Dec. 14										1	200
Dec. 21		20	110				4				144

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TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION DES PLAINES—Continued

Plankton organisms (in cubic standard units) in 1 c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Radiolites	Copepodites	Sperm., etc.	Total
1920											
Jan. 4		18	48			5		3		9	73
Jan. 11			48					1			49
Jan. 18		5	144			24		16			189
Jan. 25		24	120					10	1		155
Feb. 1		47	110		10			21			198
Feb. 8		33	42		7			35			117
Feb. 15		40	100					80			180
Feb. 22		50	142					91			283
Mar. 1			1,007		5	18		19	3		1,049
Mar. 8	100		201			100	41			25	422
Mar. 15		32	844		20	3		24			978
Mar. 22		40	200						15		255
Mar. 29	10	20	120				80	5			235
Apr. 5		20	80				80				280
Apr. 12	72	24	500			65	80				696
Apr. 19	15	22	400			22	80				549
Apr. 26		23	198			23	167				411
May 3	280	20	620		20	80		3		5	1,128
May 10	1,702	200	2,404			607	1	10	30		4,954
May 17	726	204	2,080			272	18	685	30		3,705
May 24	1,086	80	2,272		10	286	4	724			4,462
May 31	200		462		1	65		26	25		789
June 7	206		2,280		10	266	18	900	11	10	3,431
June 14	408		1,178		5	244	272	777	64		3,123
June 21	915		1,200		11	274	162	14	652		3,553
June 28	226		1,238		8	272		5	126		1,869
July 5	12	54	480			66	12	3	154	13	768
July 12	220		1,261			225	13	35	66	11	2,400
July 19	408	117	2,782			406		803	108	7	4,424
July 26		18	2,206		3	282	36	5	145		3,715
Aug. 2	26	54	1,755		5	144	3	5	272		2,279
Aug. 9	126		2,624		6	72	18		266		3,046
Aug. 16	72		2,637			288	2	5	247		3,449
Aug. 23	102	30	1,180	25		155	51	20	365	16	1,844
Aug. 30	64	58	1,652	21	102	186		80	422	28	2,685

STATION 200

1921											
Oct. 5	274		1,006			144	138	26		72	1,760
Oct. 12	244		260			104	46				754
Oct. 19	744		212			56	147	7		122	1,288
Oct. 26	187		289	29		55	128	6			607
Nov. 2	341		220				36	2		81	700
Nov. 9	105	40	275	30			51				531
Nov. 16	1,020	180	428			120	124				1,852
Nov. 23	44	22	440			174	18			22	722
Nov. 30	155	24	274	24	3	34	64			23	729
Dec. 6	47	30	220	45			100	4	23		397
Dec. 14	406		220			86	24	20			686
Dec. 21	180		270				10		18	54	541
Dec. 28	26		126			7	10	3		14	186
1922											
Jan. 4	90	80	180	10		10	91				411
Jan. 11	104	20	206	52		24	100				526
Jan. 18	31	52	157	65			17			13	358
Jan. 25	154	26	91	65	2	12	8				358
Feb. 1	40	20	90	40			192				402
Feb. 8	23	24	48				12			9	126
Feb. 15	221	13	78	65			16			13	496
Feb. 22	78	117	195				62				452
Mar. 1	10		72				15			6	103
Mar. 8	152	140	42	140	8	14	184				576
Mar. 15	96	180	220				26	16			632
Mar. 22	90		204	20		100	48			20	482
Mar. 29	200	64	220			94	19			48	525
Apr. 5	204	96	288				221			16	725
Apr. 12		40	680				262			90	1,072
Apr. 19	80	11	196	11		11	29			55	275
May 6	52	12	224			120	217		22	12	790

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 285—Continued

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Radiolarians	Crustaceans	Spores, etc.	
1900											
May 10.....	1,200	18	200			60	172	8			1,760
May 17.....	374	66	154			12	111				717
May 24.....	712	32	240			66	268			28	1,607
May 30.....	387		99	44		32	202			11	885
June 7.....	48	16	158			27	261			80	613
June 14.....	110	25	220			11	12			26	613
June 21.....	16	140	200			80	30			18	600
June 28.....	144	18	270			18	100			20	600
July 5.....	124	20	104	20		12	100			20	600
July 12.....	60	52	120		2		61			20	307
July 19.....	120	22	232			60	100	5	20	22	747
July 26.....	19	74	418	20		20	20	10		19	600
Aug. 2.....	26	16	106		8	185	180	8		1	606
Aug. 9.....		35	180	20	8	26	120	8		1	371
Aug. 16.....		190	220	12		60	120			100	660
Aug. 23.....	60		271		2		14			20	378
Aug. 30.....	70	20	650		4	90	48		90	60	1,000

STATION BRANDON BRIDGE

1901											
Oct. 5.....	506	40	1,100				80				1,760
Oct. 12.....	148		110			20	205	9		42	634
Oct. 19.....	260		278			12	15		4		569
Oct. 26.....	646		272			22	90	5		23	1,031
Nov. 2.....	190		234		1		279			1	747
Nov. 9.....	200	104	200			20	181				1,005
Nov. 16.....	180	20	480			20	30				730
Nov. 23.....	70	80	480			20	30				680
Nov. 30.....	244	11	154			22	27	4		8	467
Dec. 7.....	40		401	10		22	22			64	461
Dec. 14.....	110	110	600	20		22	22	4			869
Dec. 21.....	110		220			22	22			16	394
Dec. 28.....	112		210			22	17			20	421
1902											
Jan. 4.....	120		180				21		180	20	540
Jan. 11.....	72		162				21				330
Jan. 18.....	25	22	55	20		22	21			7	970
Jan. 25.....	176	44	50	100		11	140			11	600
Feb. 1.....	4	20	170	12			120	5			379
Feb. 8.....		60	60			20	222			10	372
Feb. 15.....	22	20	142				47				323
Feb. 22.....	20		112		20		190				322
Mar. 1.....	5		160			20	20			10	315
Mar. 8.....	64		142				275			12	574
Mar. 15.....	200	16	272			16	177	12		48	620
Mar. 22.....	220	80	120			20	20				600
Mar. 29.....	720	90	224				21			40	1,119
Apr. 5.....	144	14	20			64	74			40	372
Apr. 12.....		200	1,000			120	60			20	1,400
Apr. 19.....	100		400			2	22	16		20	600
Apr. 26.....	140	64	220			64	40	8			600
May 3.....	640	22	404			2	208			24	901
May 10.....	240	22	162			11	27	11		61	618
May 17.....	649					112	208			22	1,189
May 24.....	612	40	204				190		40	16	916
May 31.....	190	19	422	16			120			26	600
June 7.....	100	11	110	11	6		20		10	44	600
June 14.....	22	60	418	9		27	41	2		27	600
June 21.....	20	117	192			22	10			26	345
June 28.....			220			22	155				327
July 5.....	20		221			2	20		112	60	400
July 12.....	6	60					60			20	746
July 19.....	192	10	220			96	41	8		24	526
July 26.....	17		272			17	16			9	322
Aug. 2.....	72	63	207			208		8			500
Aug. 9.....	87	20	120				127				300
Aug. 16.....	16	6	200		20		145				300
Aug. 23.....	20	20	200	20		20	120	8		20	400
Aug. 30.....	20	120	210			20	28	8			401

202 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION KANKAKEE RIVER

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Rhizopods algae	Green algae	Fungi	Rhizopods	Fungi-ciliates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1901											
Oct. 6	30		200			22				10	262
Oct. 12	10		200			20				10	240
Oct. 19	20		90							8	118
Oct. 26	104	5	144			40	20				213
Nov. 2	60		120	20		20				10	230
Nov. 9	84		102			20					212
Nov. 16	72	60	64			8					200
Nov. 23	40	80	200								320
Nov. 30	70		110				1			20	291
Dec. 7	22		110			22				1	155
Dec. 14	20		100							17	207
Dec. 21	10		120							1	141
Dec. 28			513			64					577
1902											
Jan. 4	18		60								78
Jan. 11			62							1	63
Jan. 18			62								62
Jan. 25	11		121							44	176
Feb. 1			110							10	120
Feb. 8			200								200
Feb. 15			200			10				9	219
Feb. 22	100		736			102				64	1,002
Mar. 1	200	170	100			20	20		6	20	600
Mar. 8	60		100			20		1			271
Mar. 15	120		900		8	20					1,048
Mar. 22	22		182							22	204
Mar. 29			600			170	12				1,000
Apr. 5			600			20	211		400		1,410
Apr. 12	120	64	200	64		107	104	11	100		1,000
Apr. 19	60		60			26	7		20		215
Apr. 26	60		260			20			20		370
May 3	20		176			77	77				340
May 10	44	11	241			22	11				409
May 17	24		278	22		22	12		22		479
May 24	60		204					2	12		286
June 7	60	11	453	11		77	2		11		604
June 14	176		620			79	11		11		910
June 21	25	7	200			42					267
June 28			91								91
July 6			60								60
July 13			72			24					96
July 20	60		82	18						22	120
July 27	27		102			9	26			27	261
Aug. 3			200								200
Aug. 10		72	648							9	729
Aug. 17			240		1	10				10	261
Aug. 24	9	18	323		2	9	1				373

STATION 200

1901											
Oct. 5	200	80	1,027			20	261	20	8	88	1,873
Oct. 12	700		606	1		60	134				1,607
Oct. 19	820	120	678				477			161	1,700
Oct. 26	600	20	420	40		120	1,000	22		91	2,263
Nov. 2	604	64	578	110			578	22		22	1,913
Nov. 9	602	20	420	60	120	20	578	71		60	1,961
Nov. 16	414	20	312				480			22	1,264
Nov. 23	100	20	300				115	7		5	600
Nov. 30	604	18	822				640				1,872
Dec. 7	121	11	184				24	11		22	349
Dec. 14	240		370				771				1,381
Dec. 21	80		240				26	12		20	380
Dec. 28	60		260				200			20	510
1902											
Jan. 4	120	24	24				107		20	24	200
Jan. 11	78	120	220			12	106				479
Jan. 18	28		184		2		120			1	335
Jan. 25	24	11	202	91			60		70		380

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 282—Continued

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green alga	Green alga	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Specimens, etc.	
1922											
Feb. 1	45		100	145		23	77	1			269
Feb. 8	22		132			11	124				269
Feb. 15	79	73	205	30			80	4		13	397
Feb. 22	55	44	372				219	7		11	707
Mar. 1	64		200			40	3				267
Mar. 8	200	34	600	231			323	20			1,607
Mar. 15	96		672			126	745			286	1,665
Mar. 22	32	180	272				78			45	615
Mar. 29	39	18	295	15		164	8	13		44	1,202
Apr. 5	264		440	23		315					1,052
Apr. 12			1,040							312	1,352
Apr. 19			945	64			253			32	1,234
Apr. 26	310		275	64		165	86	4			810
May 3	60		200			40	236			10	606
May 10	51	44	330			55	170				650
May 17	288	6	484				260	12		32	1,082
May 24	146	178	200			95	200			18	1,138
June 1	143	11	220			33	20	14			410
June 8	171	100	154	10		100					535
June 15	35	37	180	14	4		27	21		1	389
June 22	10	280	270	20			133	43			675
July 1	30	10	110			30	43	4		30	247
July 8	114	30	130		3	30	25			40	313
July 15	268	13	284			67	250			13	795
July 22	144	16	277			65	79				565
Aug. 2	6	33	93			64	58			18	208
Aug. 9	105	72	245	15		43	19				464
Aug. 16	54	72	206	28		63					423
Aug. 23	30	10	190		5	100	267	15			708
Aug. 30	37	178	242	21		11	25	3	55	3	569

STATION LA SALLE

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green alga	Green alga	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Specimens, etc.	
1921											
June 22	794	2	479	80	1	123	28	9			1,407
June 29	155	140	620	30		180	24	22			1,941
July 6	100	64	270	48			112	6			572
July 13	100	72	480	144	10	80	26	78		50	1,000
July 20	202	60	440	80		30	67	20		40	1,042
July 27	88	144	373	27	2	100	10	66		8	686
Aug. 10	148	104	408				3	80			713
Aug. 17	96	52	312	26		53	85	26		20	687
Aug. 24	37	26	171			26	167	6			426
Aug. 31	79	373	406	11		30	120	21			1,003
Sept. 7	60	110	260	50		140	64				642
Sept. 14	600	100	600			120	55				2,245
Sept. 21	224	70	770			100	10	60		4	1,168
Sept. 28	201	58	545	24		76	8	5		1	968
Oct. 5	161		200			90	177	15	100	24	1,187
Oct. 12	400		204			90	261	15		97	1,467
Oct. 19	202		231				141	7		11	795
Nov. 2	187	10	400			110	170	11			887
Nov. 9	202	23	200				96	6			526
Nov. 16	227		111		2		178				1,111
Nov. 23	60	12				11	20	1		12	263
Dec. 7	111	35	170	11		23	201			100	1,143
Dec. 14	44		200			122	200			44	600
Dec. 21			404		4		26			110	644
Dec. 28	130	18	210				405	3			763
1922											
Jan. 4	20		200			20	122	6		3	443
Jan. 11	200	140	200		13		200				643
Jan. 18	130	60	70				20	5		10	323
Jan. 25	54		94	20		6	25				209
Feb. 1	80	18	134	14		10	177	4		6	439
Feb. 8	60	15	190				200			15	510
Feb. 15	60	6	104				204			15	431
Feb. 22	204		440		13		420	20			1,297
Mar. 1			322		6	60	114			110	671
Mar. 8	164	55	205	60		22	91				692

204 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION LA SALLE—Continued

Date	Plankton organisms (in cubic standard units) in l. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Frag.-of-larvae	Ciliates	Rotifers	Crustaceans	Spores, etc.	
1902											
Mar. 12	36	100	443		6		306				991
Mar. 22			600				5				605
Mar. 29	110		230				25				365
Apr. 5			300				5				305
Apr. 12			400								400
Apr. 19	145		90				15				250
Apr. 26	400		241			25	13	6		10	795
May 3	243	18	102				23				386
May 11	300		600			304	714			66	1,974
May 17	113	31	207			7	156			23	608
May 24	131	44	110	11		11	125				433
June 1	34	34	714							136	919
June 8	20	200	300			25	66			20	691
June 14	145		100			10	215				475
June 21	15	170	310								505
June 28	117	60	231				42	10		10	460
July 5	34	171	150	10			30	4			409
July 12	91		311			70	74	9		21	476
July 19	206	217	403			77	91	3		23	1,110
July 26	88	84	540			185	165	6		23	1,091
Aug. 2	38	25	305	23		32	83			11	732
Aug. 9	30	60	340			20	5			26	471
Aug. 16	26	150	432				2	5		26	645
Aug. 23	6	30	301				12	20		14	389

STATION HENRY (1902)

1902											
Mar. 22	31		400				13				441
Mar. 29			273								273
Mar. 29	147		306								453
Mar. 31	44		300								344
Apr. 7		60	714			23	4	20		179	1,091
Apr. 12	68		272			3	6			100	411
Apr. 19			381	13		11	6			11	381
Apr. 26			440				213	1		130	773
Apr. 26		80	200				5			42	425
Apr. 26		24	740							136	919
Apr. 26	130		200			74	10	37		90	600
Apr. 26	107	1	340				187			17	731
May 3	336		300				9			30	789
May 3	470	10	200			40	83	00		20	943
May 10	61		235			1	2	1,165		11	1,464
May 12	219	64	528			96	8	1,120		10	1,941
May 14	243	110	815			22	44	204	00	8	1,606
May 19	135	44	343			4	287			32	706
May 26	300	33	187			55	9	2	5	22	676
June 2	96	64	1,102			224	544		201	224	2,495
June 6	130	77	300			108	150		47	11	971
June 6		14	470			42	130	2	300	43	1,081
June 6	64	66	407	11		119	225	4	60	11	900
June 14	100	10	300			100	155	26	31	8	804
June 20	18	30	600	15		60	30	80		93	1,000
June 26	96	10	400			40	67		31		733
June 27	140	230	530			220	371			65	1,461
June 30		204	635	66		110	96			91	1,171
July 6	155	34	458			112	5			22	797
July 13		30	382			16	5				423
July 15	200	60	817			30	22				1,129
July 19	179	66	372			110	110				1,063
July 21	23	114	590				101			23	800
July 26		161	672			31				36	843
July 26	100	126	611	13		78	4	15		39	1,069
Aug. 1	38	163	986			102	306	00		103	1,492
Aug. 6		73	714	68		11				170	1,000
Aug. 9	443	344	1,378							203	2,168
Aug. 12	34	4	703			200	60	16		34	784
Aug. 18	47	85	435	34		130		10		54	1,206
Aug. 23	143	94	608	30		84	300	18		54	1,206
Aug. 24	60	130	1,300			60				40	1,690

13 kinds.

16 kinds.

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 179

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1921											
July 1	14	238	1,800			210	10				2,372
July 6		176	1,182			187		25		19	1,589
July 13	32	144	1,775			788		80			2,799
July 20	80	393	440		3	96	6	40	93	58	1,179
July 27		601	1,309			19	34	25			1,838
Aug. 3	130	143	330	20			3		8	65	698
Aug. 10	91	206	637			170	1	8		12	1,126
Aug. 16	39	32	651	20		91	230	11		13	1,027
Aug. 19		130	336			108	8	9			861
Aug. 23	60	120	262			100	1		166	61	770
Aug. 26	52	455	656			200	2			39	1,894
Aug. 30	52	13	617			92	2		81	39	766
Sept. 2	40	250	840			15	40	8		30	1,230
Sept. 6		52	607		8	117	52		10		788
Sept. 9	32	39	729	13		57	4			65	999
Sept. 13	16	96	578			208		5		65	901
Sept. 16	140	70	230			40	53	7			540
Sept. 20	130	30	429			75	1	4	7		676
Sept. 23	216	8	254			16				34	804
Sept. 27	16	16	249	16	1	16	1			33	347
Sept. 30	64	224	176			8	1				473
Oct. 4	288		316		1					16	621
Oct. 7	400	48	432	8		8		14		40	960
Oct. 12	182	65	169			39		4		15	439
Oct. 14	195	39	209				4	2			462
Oct. 18	64	248	168		5	64	33				582
Oct. 21	165	33	352	22		34	179	9		55	849
Oct. 25	121	168	308			44	4	8	8		656
Oct. 28	200	24	168		1		96				489
Nov. 1	240	348	457			34			3		1,072
Nov. 4	328	32	257	16	1	8	6	7		16	671
Nov. 7	143	120	264		13	55	7				602
Nov. 12	336	48	368				4				766
Nov. 15	242				5	46	44		4	45	385
Nov. 18		65	733			88	106	6			519
Nov. 22	100	100	480		13		47	20			680
Nov. 25	330	23	308		2	105	23			44	834
Nov. 29	132		266		7	22	4	6			567
Dec. 2	123		176								308
Dec. 6	31		294			132	5			122	696
Dec. 9	33		143		4		46			65	261
Dec. 12	94		120				1				225
Dec. 16	45		70		1	16	28			4	206
Dec. 20	110		308		6		34				438
Dec. 23			140			40	22	3		180	335
Dec. 27	16		96		1		68				171
Dec. 30	20	20	70			90					200
1922											
Jan. 3	20	16	160							8	204
Jan. 6		40	150				11				201
Jan. 11	55		132		1		12				200
Jan. 13	60		160				5			20	245
Jan. 17	30	10	150	20			21				232
Jan. 20	60	20	70			10	66				236
Jan. 24	24		132	16			24	3		16	235
Jan. 27	30		20		11	30	165			14	266
Jan. 31	45		285				232				562
Feb. 3	33		48		6		129				215
Feb. 7	130		180				125				395
Feb. 10		10	150			1	73				234
Feb. 16		13	299				72	29		37	444
Feb. 17	40		170			40	98				348
Feb. 21	165	11	275				20			13	484
Feb. 24	473		242		3		103	18			830
Feb. 28			253			33	150	9		33	487
Mar. 3	70	20	170			20	117	6		21	434
Mar. 7	33	32	311			16	92	10		80	573
Mar. 10	96	48	326				26	1		32	733
Mar. 15			286			88	34			66	474
Mar. 17	22	178	486				91			22	797
Mar. 21			110				7			66	183
Mar. 24		16	304				66	8		80	471

206 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE No. 5'.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 179—Continued

Date	Plankton organisms (in cubic standard units) in 1 c. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	
1922											
Mar. 20			306				94				400
Mar. 31			382			23				110	494
Apr. 4	110		675		15		30			45	875
Apr. 7	144		288							48	480
Apr. 10	48	34	216				220			3	511
Apr. 14	72		192			24		9			287
Apr. 18	40		120				3				163
Apr. 21			144						19		163
Apr. 25	90		340	10		80	330				830
Apr. 28	48		240			48				24	860
May 3	348	36	276			156	6	365	12		1,190
May 5	432	34	216			168		47			857
May 10	42		687			48	131	298	3	16	1,163
May 12	462	11	308	11		297	7	148			1,244
May 16			980			380	390	532			2,382
May 19	440	22	616			66	178	8			1,330
May 23	570	20	1,110			324			65		2,092
May 25	256		1,152			180			132	64	1,794
May 29	96	64	1,312	64		704		16		96	2,332
June 2	16		320			226	206	3	43	10	880
June 6	27	16	304			253	3	3	17	86	709
June 9		30	430			581	180	2	479	60	1,690
June 12	112	32	384	180		480	2	20	100	32	1,323
June 16	22	11	680			253	4		464	33	1,367
June 20	104	80	942			72			190		1,368
June 23	58	56	658			21		18		63	905
June 24			537	8			11		80	16	681
June 30	100	110	900			4	136	4	12	31	1,267
July 3	16	32	456			88	1	1	3	32	629
July 7		28	567		3	21	5		216	7	847
July 11			680		21	34				104	839
July 14	70	35	392	14		35			10	14	671
July 18	16	21	484	42		77	3	3	11	14	671
July 21	90	54	379	30		70					813
July 25	9	55	951			187				121	1,303
July 28	136	450	1,223			372	102	35		119	2,407
Aug. 1	32		706			180	64		5	16	965
Aug. 4	60	130	740	40		20		30		20	1,020
Aug. 7	64	112	1,271	1		293	7	84		48	1,690
Aug. 11	42	302	784	28		149		71		66	1,442
Aug. 15	40	82	779			323		84		40	1,267
Aug. 18	48	138	1,477			367	6	121	38	66	2,208
Aug. 22	48	539	1,386	48		1,012	96	154		24	3,067
Aug. 25	55	68	1,374			375				17	1,790
Aug. 28		191	944			113	13	7	7	48	1,323

STATION MOSSVILLE

1921											
Aug. 30	26	68	907			204	8			26	
Sept. 2	290		2,587	26		790	139	17	10		3,808
Sept. 6	64	16	1,152			172		4	5	64	1,417
Sept. 9		93	987			310	2			13	1,411
Sept. 12		96	486		9	112	1		8		693
Sept. 16		28	266		7	32	1		21	35	260
Sept. 20		5	355			181	3	4	13	10	341
Sept. 25	10	61	430			21			6		334
Sept. 28		70	329		2	40			3	18	438
Sept. 30		70	360	30	1	30	1		103	90	948
Oct. 4	90	30	631			130					1,071
Oct. 7	80	24	126		2	16	32	3	1	32	319
Oct. 12	385	70	331			110	20			20	686
Oct. 15	104	152	608	40		56		17		30	1,001
Oct. 18	138	150	216			6	2			2	514
Oct. 21	27	9	260			16	99				515
Oct. 25	165	44	496		13	143	1			22	374
Oct. 28	80	16	216		3	32	34			33	413
Oct. 31	370	80	330	30		110		10	40	10	970
Nov. 4	272	176	336					3			787
Nov. 7	300	280	363				3		3		948
Nov. 12	200	110	385			11	2			33	739
Nov. 16	120		165				1	48		15	345
Nov. 18	228	15	330	30	9		1			30	640
Nov. 22	130	60	553					8		48	796
Nov. 23	187		344		18	11			2	11	679

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 101

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1921											
June 21	80	80	1,511			80	33	7	80	10	1,879
June 27	80	64	1,109			193	129		187		1,792
July 1	96	340	1,878	48		644	14	357	803	16	3,664
July 6		187	1,186			337		85	166		1,664
July 13	64	440	1,163		33	595		230	304		2,728
July 20		1,121	676	13		634		347	1,200		3,298
July 27	65	206	871			166		97	811	39	1,966
Aug. 3	13	117	639	39		78	2	81	94		1,032
Aug. 10	44	65	704		4	85		23		22	967
Aug. 16	64	192	1,943		6	13	6	6		64	2,264
Aug. 19	1	39	419			37					490
Aug. 23		13	781	13	3	196	9		13		1,026
Aug. 26		13	613			130	7		5	26	839
Aug. 30	80	180	1,241		48	240	6	23			1,790
Sept. 2	70	370	740			41	53	64	5	70	1,413
Sept. 6		65	963	36		354		16	62	13	1,378
Sept. 9		13	854	13	104	449	130			7	1,690
Sept. 13	30	80	290			80	370			10	750
Sept. 16	3		275	5		133	90		3	10	521
Sept. 20		25	305			144	122		50	15	641
Sept. 23	23	40	330		3	121	122		13	20	610
Sept. 27	60	40	413			40				10	593
Sept. 30	50	81	501	30	1	170	60			10	1,026
Oct. 4		11	48	456		72	1	3		8	599
Oct. 7	104		916	52	10	52	12		6	104	1,266
Oct. 12	99		362			132					634
Oct. 14	104	18	304			16	25		7	16	468
Oct. 16	215	65	230	5		80	25		1		610
Oct. 21	273	434	533			126	10				1,367
Oct. 25	231	66	462	11		122	1				668
Oct. 28	1,037	352	686			225	59		9		2,366
Nov. 1	186	43	290	26	70	136			14	43	780
Nov. 4	104	32	156	13	48	2					374
Nov. 7	280	140	623		80						1,120
Nov. 12	224	64	460					33			900
Nov. 15	270	13	360			78			17		767
Nov. 18	160	16	240								416
Nov. 22	144	40	224	16							427
Nov. 25			110				3			11	136
Nov. 30	48		416			78	19				561
Dec. 2	33	11	375			11	3				323
Dec. 6	16	40	267			104	3				480
Dec. 9	44		330			11					385
Dec. 13	33	3	374			4	9	3		4	439
Dec. 16	86	33	167			11	5				515
Dec. 20	77	66	286			22	1				482
Dec. 22	32		433				1		6	16	467
Dec. 27	48		56				1			2	197
Dec. 30	40		160			8	1			8	217
1922											
Jan. 3	48	8	176			16					343
Jan. 6	28		280			38	66			14	446
Jan. 10			110			8	2		3	16	139
Jan. 13	36		282			18	3		6		315
Jan. 17	60	64	348		6		3	2			526
Jan. 20	72	6	196			30	8	12			328
Jan. 24		21	77				1			14	113
Jan. 27	83		130			50	40				300
Jan. 31	36	9	96			9	34			9	187
Feb. 3	42		105	14		8	1				196
Feb. 7	36	63	49			7	1			56	204
Feb. 10	36	37	189			37	4				369
Feb. 14	27	9	99				21			9	167
Feb. 17	70	14	154		2	7	36				260
Feb. 21	31	56	260				3				360
Feb. 24	44		187			4	9			11	325
Feb. 28	113		382				31				486
Mar. 2	66		864			22	8				713
Mar. 8	84		446			30	40				564
Mar. 10	70		165				8			30	268
Mar. 14	144		406				32	7		46	621
Mar. 17	10		96				1	4		10	106
Mar. 21	30		160			36	11	8			219

208 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 106—Continued

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustacea	Spores, etc.	Total
1922											
Mar. 24	113		224	90		33	15	3			488
Mar. 28			140			10	2		8	30	180
Mar. 31	216		964							73	1,189
Apr. 4	60		144			12	1				217
Apr. 7		99	264								363
Apr. 11			206			44	4	7			211
Apr. 14	180		876			24	13				781
Apr. 21	34		168			24	146	2			334
Apr. 28	108		123			26	64	4			219
May 3	120	60	263			226	120		33		613
May 6	96	34	607			208	10	20		34	1,029
May 10	121	66	289		6	260	72	194		33	1,680
May 12	16		225			35	226	40	41	17	686
May 16	120	48	433			348	213	126	16		1,516
May 19	136	11	681			220	102	119	624	32	1,707
May 26	260		1,144		8	454	3	31	870	48	2,477
May 29	268		1,181			462	73		117	30	2,118
May 30	44		602			206	1		147	33	1,204
June 3	33		242			242	201		120	33	871
June 6	15		661			1,022	4	12	211	33	1,846
June 9	22		436	10		226	72	7	262	40	1,274
June 12	12		266		1	254	73	5	467	32	1,141
June 16	23		661			662	213	12	161		1,620
June 20	60	60	670			70	51	3	126	10	949
June 23	13	60	994			122	99		40	32	1,507
June 30	22	11	1,022			212	45	11	70	99	1,404
July 2	166	105	1,227			226	16	45	8	2	2,442
July 7		21	531		1	9	30	6	19	9	640
July 11		144	424		3	72	4	2	6		665
July 14	110	122	946			264	13		60		1,545
July 18	22	60	20	112	9	666	70	3	15		1,022
July 21	24	168	1,770	13		144	64		15	24	1,920
July 25	64	112	1,198	16		220	90	8	11		2,110
July 28	68	94	1,106			260	6		17		1,673
Aug. 1	80		1,212			271	66	46	104	48	2,090
Aug. 4	86	142	1,620	22		266	4		104	22	2,266
Aug. 8	22	240	1,180	16	3	220	12	20		48	1,908
Aug. 11	22	112	1,220			226	6	2			1,660
Aug. 15	26	91	1,612			416	291	8		12	2,424
Aug. 18	24	168	1,125		7	762	96	215	48	24	2,499
Aug. 22		64	1,190			226	76	99		22	1,716
Aug. 25	16	192	2,626			704	192		120	126	2,897
Aug. 28		162	1,626			824	4	22		16	2,498

STATION 121

1921											
June 10	160	160	70		20	240	25	6	220	10	1,120
June 25	242	220	800			418	265	1	212	22	2,112
June 30	94		802						267	66	1,229
July 6	81	180	726			81		82	121	106	1,296
July 12		418	945			416	2		167		1,961
July 20	22	1,168	620			60	7	24	29	16	2,045
July 27	18	945	504			26	1		212	18	1,726
Aug. 3	104	1,196	910			264	3	22	268	26	2,072
Aug. 10		261	827			145	122	20	62		1,360
Aug. 17		196	442			29	221	8	20	60	972
Aug. 24	26	122	666			26		22		62	1,146
Aug. 31	22	204	992	224	6	224	172	268	9	22	2,296
Sept. 7		81	702			162	66				1,020
Sept. 14		22	182			200	260			16	627
Sept. 20	64	72	241			126	93				666
Oct. 5	20	60	660	48		75	2		6	48	922
Oct. 12	64	64	706			22	3				961
Oct. 19	240	48	244		3	80				8	728
Oct. 26	204	262	421			122	2			12	1,024
Nov. 2	810		810	20	10	120					1,210
Nov. 9	270	18	566			64	6	31			967
Nov. 16	221	22	262			44	1				661
Nov. 23	126		468			16	14	8		22	641
Nov. 30	22		219				2	27		11	262

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 123—Continued

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1921											
Dec. 8.	55		418			33	2	11		4	533
Dec. 14.	46		184			16	1			10	265
Dec. 21.	100	50	190							30	370
Dec. 28.	46		886			12		53		12	988
1922											
Jan. 4.	14		147			14		1		14	190
Jan. 11.			190			10				20	230
Jan. 18.	27		171				36			9	243
Jan. 25.	30	10	135				1			9	185
Feb. 1.	43	8	152				28			9	230
Feb. 8.	9		196				90			8	303
Feb. 15.	28	52	208			16	96			8	385
Feb. 22.	80		640							120	1,040
Mar. 1.	122		280			22	35				697
Mar. 8.	80	10	870			30	87	60			1,087
Mar. 15.	136		1,224				2			66	1,428
Mar. 22.	121		284			23	7		11	11	477
Mar. 29.	26		385			64	1		8		520
Apr. 5.			880							120	1,000
Apr. 12.	480		840		50					40	1,470
Apr. 19.	140	20	880							26	1,066
Apr. 26.	112	26	235								373
May 3.	120		480			80	1				681
May 10.	132		380			73	73			26	684
May 17.	976		333	24	1	216	72	15	4	10	1,377
May 24.	1,410	35	640			658	68	7			2,819
May 31.	870	180	1,169			619	113	7	120	20	3,000
June 1.	680	144	833			372	5	25	75	18	1,930
June 8.	60		420	2		715	45	6	200	23	1,586
June 15.	90	22	381			88	3		156		660
June 22.	80	271	2,080	40	80	540	170	10		40	3,321
June 29.	217	630	2,862	40	80	930	11	22		42	4,726
July 6.	216		1,192			360	8	8	14	229	1,976
July 13.	54	73	793	18		270	36	19	5	54	1,315
July 20.	34	425	1,122			102	46	38	26	34	1,662
July 27.	67	182	599			166	68	61		66	1,088
Aug. 3.	192	1,312	3,631		6	806	6	35	240	8	5,281
Aug. 10.	32	980	1,486			507	300	353			3,481
Aug. 17.	32	264	794		15	122	110		12		1,330
Aug. 24.	32	369	1,134		22	908	146	75		56	2,794

STATION SPOON RIVER

1921											
June 19.	54		180			18	14				366
June 26.			1,800	120		60		2			1,982
June 30.			1,900				1				1,901
July 6.			702			195					897
July 13.			864			72			26	72	1,034
July 20.			780	60		210					1,050
July 27.			804	46		190			16	46	1,096
Aug. 3.		3	2,820								2,823
Aug. 10.	64		704			98					866
Aug. 17.	48		518			260				1	1,106
Aug. 24.	180		675			192	11			23	1,076
Aug. 31.	240		284	48							672
Sept. 7.	76		1,300	30		75	5				1,786
Sept. 14.			804								804
Sept. 21.			1,036							48	1,104
Oct. 5.	46		1,300			186					1,492
Oct. 12.	61		1,508	61	11					61	1,700
Oct. 19.	80		1,200			30					1,280
Oct. 26.	240		1,800				4			40	2,104
Nov. 2.	210		1,300	30		60	1			30	1,631
Nov. 9.			256	40	7					15	277
Nov. 16.	180		690	60							930
Nov. 23.	46		210			45	7			15	615
Dec. 6.	44		528			44					616
Dec. 13.	16		290			80				8	372
Dec. 20.	16		720							30	830
Dec. 27.			336								336

210 POLLUTION AND PURIFICATION OF THE ILLINOIS RIVER

TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION SPOON RIVER—Continued

Plankton organisms (in cubic standard units) in 1 c. c. of water											
Date	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Flagellates	Ciliates	Rotifers	Crustaceans	Spores, etc.	Total
1922											
Jan. 4	32		310			32	31				467
Jan. 11	32		672			3	1				707
Jan. 18	30		170			10	30				330
Jan. 25	26		136			40					302
Feb. 1	60		162	12		36	3				373
Feb. 8	96		620			30	15			1	796
Feb. 15	77		231			22	2				332
Feb. 22			1,572							109	1,794
Mar. 1	364		682			67	66				1,079
Mar. 8	126		441							62	630
Mar. 22	167		1,630							137	1,869
Mar. 29			372							123	794
Apr. 5	60		390			30	7				487
Apr. 12	100		420				3			30	553
Apr. 19	136		360	8		24	3	3	13		580
Apr. 26	60		380			60	3		12		713
May 4	140	36	290					3	12	39	713
May 11	110		326			66			41	22	787
May 18	170		630								800
May 25	102		748								850
June 1			736			34	4				814
June 8		17	406			34					459
June 15			760							40	800
June 22			634			224				32	890
June 29	44		862			190	73			33	1,102
July 5	280	126	794			422				16	1,638
July 12	351		3,120			32					3,543
July 20	66		968			44	1				1,101
July 27	36		7,492			442	2				7,970
Aug. 2	234	26	1,626		2	182	5	3			2,068
Aug. 11	55	23	464			362	6			22	963
Aug. 18	26		252			218				26	527
Aug. 24		102	662				4				769
Aug. 31			1,626			66	46	2		11	1,753

¹ Nearly 60 per cent. *Achnanthes*.

STATION 100

1921											
June 12		100	70		3	190	50		103		500
June 24	40	360	200		270	300	123	5	24	55	1,265
July 1			220		11	60	36		12	115	436
July 7		65	442		4	1	6		30		538
July 14		461	1,118	104		100	13	23	190		2,406
July 20		364	351			65		2	7	13	922
July 26	42	1,204	364			280	284		410		2,864
Aug. 4	16	464	112		7	3	62		196	14	806
Aug. 11		230	176		1	64	120	30	5		734
Aug. 18	16	1	302		30	360	230		12		967
Aug. 27		80	144				224			2	450
Sept. 1	60	160	690	10	7	40	105	21	30	1	1,174
Sept. 12	40	230	240				175				675
Sept. 15		39	221	39		91	377				767
Sept. 20		280	2	1,724	18	2	41	30		30	2,117
Oct. 6	63	224	432			2	78	76	27		967
Oct. 12	180	195	735		60	196	90		41	15	1,511
Oct. 19	64	96	176			18	5			23	379
Oct. 26	230	15	960		5	75	90				1,475
Nov. 2	902	44	336	11	9	77	7				1,080
Nov. 12	342	66	99		1	11		5	2		426

TABLE NO. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION SANGAMON RIVER

Date	Plankton organisms (in cubic standard units) in 1 c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Frag. diatoms	Chlorophytes	Red-trees	Crustaceans	Spores, etc.	
1921											
June 13	100	51	750			1,301	602	3	28		3,085
June 24	144	48	1,704			66	16	3	11		3,032
July 1		300	1,520			40	64		31		3,055
July 7		494	780			269		4			3,033
July 14		1,000	1,480			101		4	49	20	3,050
July 20	78	1,000	1,153			280	4	2	9		3,067
Aug. 4		1,000	973			413	2				3,088
Aug. 11	27	1,188	1,883			34			27	3	3,135
Aug. 18	40	230	827	20		60	11	1	20		3,139
Aug. 25	27	234	1,757		9	26	7	18	37		3,132
Aug. 27			1,000			230	3			40	3,043
Sept. 1		40	880			140	3			1	3,064
Sept. 12		186	1,350			147		1	7	4	3,087
Sept. 18		37	1,404			263	40				3,144
Sept. 22			1,380			300	90	4		20	3,174
Oct. 6		80	940			184	134			13	3,131
Oct. 13		200	946			300	3				3,149
Oct. 19	223	144	973			180	2			48	3,126
Oct. 26	206	330	1,412			330	2	18		30	3,200
Nov. 3	276	46	816			130					3,268
Nov. 12	276	176	367			77	3	28			3,000

STATION 25

1921											
June 18		40	50	30		50	815				975
June 25		126			3	129		78	130		366
June 26		40				60	263				333
July 5	98		493	34		221	535	2	13		1,373
July 12	184	976	407		130	170	91	13	10		3,021
July 19			464			144	481	16	66		3,336
July 26	30	1,310	510		20	260	450		90		3,080
Aug. 2		280	788		1	112	82		30		3,203
Aug. 9	33	33	320			96	48				526
Aug. 16	64	672			8	195	226				1,380
Aug. 23	104	78	910			52	104	10		78	1,336
Aug. 29	76		760			52	6			3	883
Sept. 7	135	180	800			106	804	6	15	96	1,000
Sept. 12		54	135			106	73		36		1,038
Sept. 22		70	774			134			105		1,037
Sept. 27			730	66		200	125	4			1,039
Oct. 4		180	973			334	185				1,740
Oct. 12	37	37	1,147			51	4	88		23	1,385
Oct. 17	119	204	731			96	80		34		1,037
Oct. 24	178	88	850			96	133	21			1,216
Oct. 31	125	234	613			78	42	9		8	1,444
Nov. 7	990	96	273		8	9	3				901
Nov. 14	180	260	840			3				40	905
Nov. 21			530					1		44	573
Nov. 28		152	98			2	3				922
Dec. 5		32	493			22		7		33	516
Dec. 14		90	324			36				18	408
Dec. 21											
1922											
Jan. 8			1,080								1,080
Jan. 11		60	940						30		900
Jan. 17		40	330	30		30		3	36		423
Jan. 31		40			7		2				49
Feb. 7		30	730							136	890
Feb. 9		60	600	30			5			45	840
Feb. 16		90	450				1				574
Feb. 20		110	264								1,080
Feb. 26		80	1,000				3		30		808
Mar. 8		136	646								1,040
Mar. 16		80	1,080			80					1,240
Mar. 21			1,040								1,040
Mar. 28		80	480							60	600

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TABLE No. 54.—Classification of plankton organisms at each station, weekly samples—Continued

STATION 25—Continued

Date	Plankton organism (in cubic standard units) in 1 s. c. of water										Total
	Diatoms	Blue-green algae	Green algae	Fungi	Rhizopods	Fleets	Ciliates	Rotifers	Crustaceans	Spores, etc.	
1922											
Apr. 4	90		880	30	9			4			923
May 12	484	88	274		2	180	24	13	62	11	1,180
May 19	790		280			20	88	3	5		1,120
May 26	1,660	160	1,080			112	280	20	1,881		5,797
June 1	880	80	1,000			88	2			80	1,990
June 6	320	60	1,120				4	13	60	40	1,577
June 14	160		7,260			88	19	7		88	1,681
June 21	60		880			80	88			30	1,038
June 28	28		978			120	188			78	1,394
July 6			1,080	30		180	4				1,394
July 13	112		1,000	100		118	28	2		52	1,400
July 19			344							22	376
July 26	81	51	784			88	118	6		17	1,076
Aug. 2	40	8	900	8		60	1	1		16	1,014
Aug. 10	80	80	1,072			300	1	3			1,456
Aug. 18	64	16	788			60	6	6		18	908
Aug. 24	24		622			60	1			5	711
Aug. 29		8	396		30	54	188	54	4		626

¹ May 26 a huge Bosmina measuring over 2,000 units was chiefly responsible for the high content of crustaceans.